DISCOVERY

THE PROGRESS OF SCIENCE

INDUSTRIAL UTILISATION OF FISSION PRODUCTS
Roberts, *Ph.D.*

RUSSIA'S EAR POWER STATION
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THE TERNATIONAL OPHYSICAL YEAR
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EDUCATION OF SCIENTISTS

FROM POLYPHARMACY TO CHEMOTHERAPY
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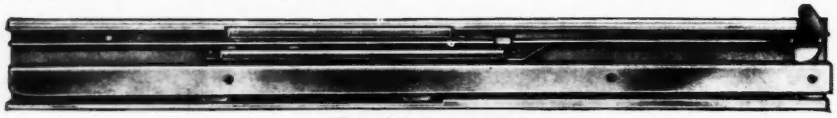

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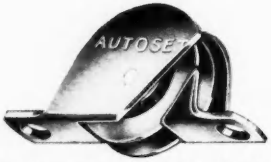

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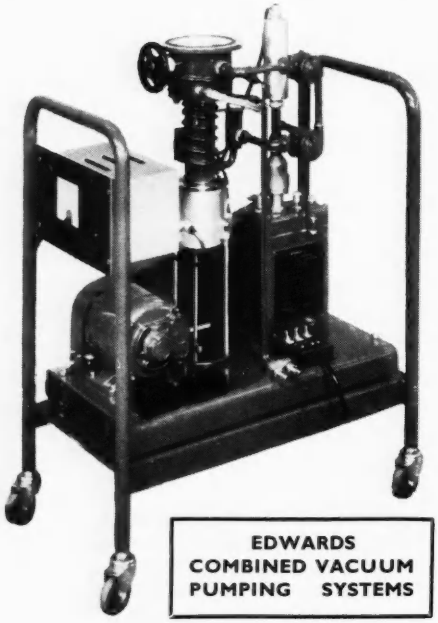

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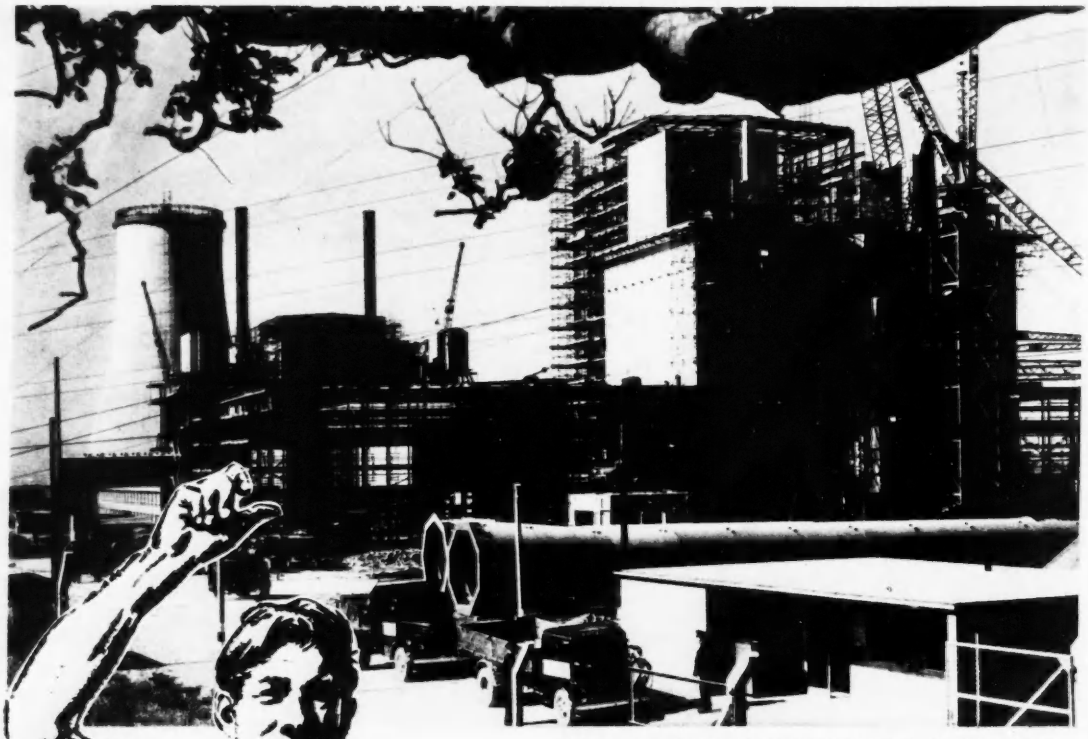

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THE MAGAZINE OF SCIENTIFIC PROGRESS

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THE PROGRESS OF SCIENCE

ATOMIC POWER IN 1956

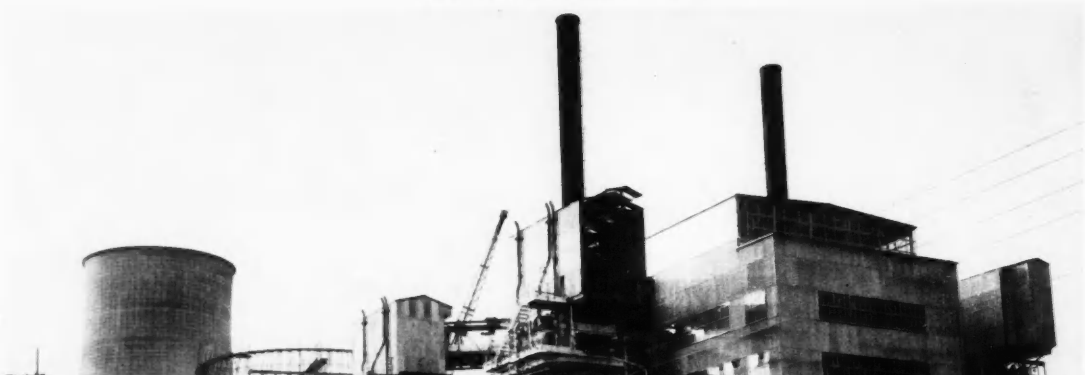
This will certainly be an historic year, an important milestone on the road leading to the full exploitation of nuclear fuels as a source of electric power. By the early summer the first of the reactors at the Calder Hall power station in Cumberland will have been made critical, and may even be supplying small amounts of electricity to the nearby chemical plant, the Windscale Works which produces plutonium. By the end of the year this power reactor will be complete, and current will start flowing into the national grid. For the first time bulk supplies of electricity will be forthcoming from a uranium reactor, and only a latter-day Luddite will be able to suppress the natural reaction of pride in this achievement of the new race of hybrids, the nuclear engineers, who have accomplished so much in so short a time.

Apart from being the first full-scale atomic power station, Calder Hall is seen to be a remarkable engineering achievement when some of the construction problems that have been solved are considered in the light of conventional engineering standards. Its construction has been difficult, not only because of its great size and essential novelty, but also because the special requirements of atomic energy have demanded exceptional design features calculated to reduce the danger of accidents. The engineers have had to meet those requirements and still maintain the over-all design efficiency. For example, all the large steel vessels which are used to contain the reactors and heat exchangers have had to be welded together with unusual care and subjected to exceptionally rigorous tests before being put into service. The concrete for the protective shields around each of the reactors has been poured and compacted under the most carefully controlled conditions to make sure that no holes were left in it and that its high density was uniformly preserved. The metals which have gone into the steel thermal shield, the cans which hold the fuel rods and the uranium itself have had to be manufactured to purity specifications which are uniquely stringent.

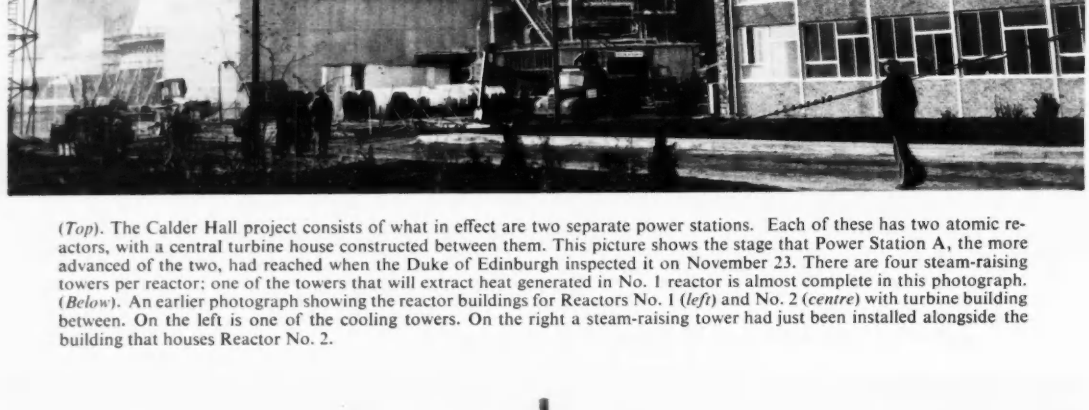
That the whole structure will have been completed in a little more than three years says much for the firms who are building it and for the men who have designed it and superintended the construction. At various times more than a hundred scientists and engineers from the Atomic Energy Authority's research and industrial groups have had a finger in the pie. The five main contractors on the site have employed more than two thousand men on construction, and have at all times kept up with the exacting schedule of completion dates which was set for them by the headquarters staff at Risley. The whole project has gone with a swing at great speed—evidence of the urgent need there is to make one power station work before the detailed design of later ones is completed.

For Calder Hall is to be the prototype of at least five other power stations. It is significant of the confidence which experience of construction has bred that the foundations for a second power unit have already been poured alongside the Calder Hall site, and that work has begun on the power station at Annan in Dumfriesshire. By the end of the decade these stations will be in operation, producing some 320,000 kilowatts of electricity and saving the country some 1,250,000 tons of coal each year.

But this is only the beginning. In the spring of 1956 private firms will put in their tenders for the first two atomic power stations which are to be built for the Central Electricity Authority. Though these will be modelled on Calder Hall and will resemble it in most constructional details, they will use enriched uranium in some of the fuel rods so as to achieve an electrical output about twice as large as that of the first stations. When these come into operation early in the 1960s nuclear power will for the first time be competitive in price with power from electric generating stations using coal or oil.



(*Top*). The Calder Hall project consists of what in effect are two separate power stations. Each of these has two atomic reactors, with a central turbine house constructed between them. This picture shows the stage that Power Station A, the more advanced of the two, had reached when the Duke of Edinburgh inspected it on November 23. There are four steam-raising towers per reactor; one of the towers that will extract heat generated in No. 1 reactor is almost complete in this photograph. (*Below*). An earlier photograph showing the reactor buildings for Reactors No. 1 (*left*) and No. 2 (*centre*) with turbine building between. On the left is one of the cooling towers. On the right a steam-raising tower had just been installed alongside the building that houses Reactor No. 2.



In this sense the engineers responsible for Calder Hall are carrying on their shoulders more than the responsibility for just one power station. Certain fine details of design and construction can best be judged when Calder Hall is working. The way in which the various parts stand up to the exacting test of actual operation will provide the Atomic Energy Authority with what it needs for drawing in the last few lines in the blueprints of British atomic power stations for the next five years. Calder Hall is very important for another reason. If the plant works as well as its designers predict, our nuclear engineers will be provided with that psychological stimulus which they will need in later stages of the programme of development.

And in the long run what is to come is going to affect Britain more directly than what the nuclear engineers have done up till now. Calder Hall and the other power stations built for the A.E.A. were designed to produce plutonium, both for military purposes and as an enriched fuel for later use in more advanced types of reactors. Each of the stations will turn out some hundreds of kilograms of this material each year. The fact that these early reactors will be used to generate electricity is incidental to their main purpose, and the fact that their design can be so easily modified to produce electricity at a price comparable with that from coal is a fortuitous result of the comparatively high cost of fossil fuel in this country. In the United States, where coal is much cheaper, a plant like Calder Hall would not be considered economic.

Indeed, with varying degrees of pride on the part of British experts, and scorn from some Americans, Calder Hall has been described as the "Model-T" of nuclear power stations. The fact that it uses graphite—not water or heavy water—to moderate the neutrons means that its physical dimensions and the weight of natural uranium used must be large. The fact that carbon dioxide is used to transfer heat to the heat exchangers in which steam is raised means that the rate at which heat is produced in the fuel rods has to be limited. If the output of heat is to be large by industrial standards this again demands a large amount of uranium "burning" comparatively slowly (and therefore the fuel cost gives rise to interest charges spread over a long rather than a short period).

There are some even more serious drawbacks. The steam which is fed to the electrical generators is not as hot and not as compressed as that employed in modern coal-burning power stations. This means that the efficiency with which the heat of the reactors in Calder Hall will be converted into electricity (roughly 24%) will be much lower than the over-all efficiency of the conventional power stations of the C.E.A. (roughly 36%). The only escape from this difficulty is to design fuel elements which can stand up to much higher temperatures—perhaps 1000°F—than those in Calder Hall can sustain (about 550°F), and to use heat exchangers which allow of a more rapid transfer of heat from the reactor to the steam circuits.

These are formidable metallurgical problems which will probably not be solved before the present type of power station is superseded altogether by ones of more advanced design. To the extent that it has a cooling system which uses liquid sodium, the fast breeder reactor at Dounreay (due to come into operation in 1958) will help to solve the second of these problems. The fact that in the last few months, as Sir John Cockcroft announced at the first meeting of the British Nuclear Energy Conference held in London at the end of November, the A.E.A. has taken up the detailed study of a homogeneous reactor in which the fuel is intimately mixed (either in solution or suspension) with a cooling liquid metal suggests that a way round the first difficulty (not a solution of it) lies in sight. Perhaps in the end, in ten years or so, we shall see realised the nuclear engineers' dream—a breeder reactor in which there is no physical distinction between fuel and coolant, so that continuous operation is possible; a small reactor, costing comparatively little to build and capable of high rates of heat output from a given volume; a reactor in which the chemical extraction of fission products is performed continuously on the spot, so that the efficiency with which neutrons are used is much higher than that in Calder Hall.

Bigger and more efficient atomic power stations will materialise in the not distant future. But the name of Calder Hall is sure of a permanent place in the history of technology because it represents a pioneering advance in power production.

ATOMIC RIVALRY

Atomic energy has become big business in recent months, and as a result fierce competition is developing between Britain, the U.S.A. and Russia. This market ranges all the way from the supply of complete atomic power stations to the large numbers of specialised instruments required at all stages of atomic research, development and production. The acuteness of this competition was brought out recently in the statement of the chairman of the U.S. Atomic Energy Commission, Mr. Lewis Strauss, who said that in ten years time the U.S.A. could be hopelessly outstripped by Russia unless it trained more scientists and engineers.

The general attitude towards atomic energy developments differs from country to country. In Britain there is considerable pride in the achievements of our atomic scientists, and there is every reason for being equally proud of what the atomic engineers have done. Over two hundred industrial firms are already in the atomic business, and the importance of export orders in this connexion is fully recognised here. But in not a few parts of the world there are complaining murmurs about the growth of "atomic imperialism". For example, a recent issue of the Indian monthly journal *Science and Culture* carried a leader headed "The Era of Atomic Imperialism". Here is a paragraph from that leader:

> A situation has now come about where the great nations of the world, the U.S.A., U.S.S.R. and U.K., have now the monopoly of atomic fuels, atomic machinery and technical knowledge, which they have so far kept as jealously guarded secrets. Now the secrets no longer

exist. Moreover these countries have spent a large amount of money and developed an atomic technology which has a great economic future. It is only natural that atomic fuels, atomic machineries and technical knowledge are now for sale to the under-developed or have-not countries something like the commercial imperialism of the European countries during the last hundred years. Today we have the beginnings of a new kind of commercial imperialism which we may call atomic imperialism. This threatened even France and to overcome this dependence the French decided to achieve what they called "atomic autonomy". The French decided to make a mighty effort, scientific, technical and industrial, to obtain all the key materials within French territory and develop their manufacture for atomic energy work within France. Recently the French have claimed to have achieved complete atomic autonomy. Our objective in India should be like the French atomic autonomy. Without atomic autonomy many of the benefits of atomic energy will only be illusory and can be quite dangerous because of the complete dependence for technology and materials on one or the other of the great powers which can thus have an economic stranglehold on the country.

Quite a few French experts on the other hand are nothing like so optimistic about their country's chance of achieving "atomic autonomy", because France is very short of scientists and engineers who can do the necessary research and development work. Many pages of *Science et Vie* were recently devoted to the views of three French scientists about France's chances in the Atomic Age. The most optimistic opinion came from Louis Leprince-Ringuet, who is in charge of nuclear research at the Ecole Polytechnique and a member of the council of the French Commissariat for Atomic Energy (C.E.A.). He is critical of the position of the institutions responsible for training scientists and engineers. Scientists and technicians should be better paid, and he added that "in this respect the C.E.A. is the best provided for of French institutions". He spoke of the poor representation of France at the Geneva atomic conference, and mentioned the lack of high-energy accelerators. A 2-MeV accelerator is due to be built, however, at Saclay (the French Harwell) which, he said, should bring new life into French nuclear research, while "there are plans, none of which are beginning to approach fruition, to equip certain universities with more effective accelerators".

Another scientist who gave his views on such matters was the physicist Maurice de Broglie. He puts the runners in the atomic research race in this order: the U.S.A., Russia, Britain ("in third place, well behind the first two", he adds), France and Canada. France, he considers, has done well on the research side considering the small financial resources put into it.

The last opinion was given by Prof. Frédéric Joliot-Curie, who is the ex-director of the French atomic energy authority. France he describes as having lost ground in atomic research since 1939, and says the reasons are lack of money, lack of material—and lack of personnel, and the means of training more. He follows up the point about France's lack of high-energy accelerators and contrasts this with the position in Britain, where the universities have fifteen such units, without taking into account the machines at Harwell. Could the giant cyclotron that C.E.R.N. is building correct this inadequacy? Joliot-Curie says that C.E.R.N. cannot provide for all French needs in this field, and then proceeds to complain that there is only one French representative on the management of C.E.R.N. as compared with Britain's five representatives—"all in very important posts", he comments. Yet France and Britain contribute equal shares (24·3% apiece) to C.E.R.N.'s revenue. He also complains about the politicians who think that France can dispense with fundamental atomic research and say, "It will be sufficient if we buy foreign patents." Says Joliot-Curie: "No doubt this solution would be to the liking of the great atomic commercial nations—the U.S.A. and Britain." Joliot-Curie then adds some very bitter remarks about an "imported witch-hunt" in the French atomic energy authority, which is not unexpected in view of the fact that he lost his post as the director of C.E.A. because of his association with the Communist Party. His conclusion is that private motives will limit the spread of the benefits of atomic power, and ends by saying that a golden age can come "only as the result of the use of sun's energy" —a somewhat surprising non sequitur.

This symposium of views published in *Science et Vie* was designed as a review of the French position in the light of the Geneva atomic conference. There can be no doubt that the conference, designed with the idea of furthering international co-operation in the atomic energy field, made it abundantly clear that there will be plenty of competition between rival firms and rival industrial nations. Perhaps this will be softened by the existence of the international atomic energy agency when that organisation comes into being. Some idea of the scale on which the atomic competition will make itself felt can be obtained from a careful consideration of the fact that British experts are already thinking in terms of an export trade for our atomic industry amounting to at least £300 million by 1975, with a home trade reaching a similar figure. (This estimate was given at the first meeting of the British Nuclear Engineering Conference.) The general attitude towards the benefits to be expected from atomic progress differs greatly from country to country. Thus the prospects look very different to British and French scientists, for example. Which is not surprising since the present situation is in fact different in the two countries. This is obvious in, say, the case of radio-isotopes. British research scientists who need these materials in their work can practically ignore the supply side; supplies of home-produced isotopes are abundant, the British output having a market value of about £400,000. A substantial part of that output is export. French scientists on the other hand have to rely to a great extent on British supplies, and not a few of them strongly regret that France has not yet organised the facilities to produce all the isotopes she needs. The same kind of situation applies to the availability of instruments used in radio-isotope research.

TREATING RADIOACTIVITY AS A ROUTINE INDUSTRIAL RISK

LEONARD BERTIN

It used to be thought that radioactivity would make it impossible to dismantle many units in industrial-scale atomic plants. This view became obsolete when the Canadian team at Chalk River reconstructed the NRX pile after an accident, a feat (described in DISCOVERY, *April 1954) that took nearly fourteen months. Almost simultaneously two members of the plutonium production team at the Windscale plant in Cumberland devised a procedure that made it possible to carry out maintenance work on radioactive production units. The following description of this development, which has revolutionised the approach to problems of maintenance and of plant reconstruction, is extracted from* Atom Harvest *published next month by Secker & Warburg. This book may be regarded as the British counterpart of Gordon Dean's book* Report on the Atom. *It gives a vivid account of the British contribution to the war-time development of atomic weapons, and tells the story of Britain's post-war atomic energy project. While collecting material for this work the author, who is the science correspondent of the* Daily Telegraph, *enjoyed exceptional facilities for visiting A.E.A. establishments and interviewing the experts in charge of research, development and production.*

In the days when the Windscale plutonium factory was planned it was assumed that the atomic reactors and the primary separation plant, which is the most active area, would be run until there was a serious breakdown and then they would have to be discarded and others built.

One of the biggest achievements of the Windscale team, in the opinion of Mr. H. G. Davey (general manager of this factory), was the way they demonstrated that this need not be true. The discovery was due in great measure to a young London University chemistry graduate, Mr. Tom Hughes, who runs the primary separation plant. After some initial operating experience he inevitably saw means of modifying and improving parts of the plant if only this were possible. Ultimately he expressed the conviction that if the plant were washed out repeatedly so that solid matter like sludge could be removed, it would be possible to enter and stay for a short time under carefully controlled conditions.

Hughes talked the matter over with Mr. Donald Fair, manager of the Health Physics and Safety Department, and together they worked out details of what later became regularly known as a "planned entry". They then put their idea to the test. It worked as they had forecast, and overnight changed the whole economics of atomic factory planning. Subsequent work showed that most of the chemical plant could be entered for short periods if the right rules were observed.

Davey could not tell me how many planned entries had been made. They had become now a matter of routine. No man goes in without holding a personal clearance that states what work has to be done, the precautions that have to be taken, the special clothing that has to be worn, and the time that he is permitted to stay on the job. This certificate is filed at the end of the job. No one can instruct him to stay longer than the time stated. It is a very specific document and even a senior engineer would not go inside without one, nor would any man dream of telling another that he could stay five minutes longer than the document stated.

As part of this work, even cutting of plant, which is all stainless steel, and re-welding has been done. They have, for example, drilled a hole in the top of a plutonium evaporator and examined it, and then, when they were satisfied that it was in good condition, sealed it up again. Three years ago it was considered quite impossible to do work in a plutonium plant.

POLYTHENE SUITS

The clothing first used for such work was of thick rubber and very much like a frogman's suit. Nowadays, instead, they wear what looks like an inflated polythene bag with a great "tail" through which air is pumped. Made of transparent, paper-thick plastic, it is so light that the body does not feel enclosed. A man is much more comfortable, and by totally enclosing him there is the guarantee that he cannot breathe even an infinitesimal amount of plutonium. The material is tough and has stood up to many tests.

Just how much the planned-entry system has meant to the atomic energy industry may be judged from the fact that a chemical process plant to serve the nuclear power station on the nearby site at Calder Hall would, in Davey's estimation, have cost £7 million or more. As a result of modifications to the primary separation plant at Windscale over the past two years the "through-put" has been considerably increased so that it can deal with all the fuel elements from Calder Hall. Further modifications now planned may enable Windscale to cope in addition with irradiated fuel from many of the reactors to be built under the £300 million nuclear power scheme.

General view of the pilot atomic power station of the U.S.S.R. Academy of Sciences. This 5000-kilowatt station began to produce current on June 27, 1955, and supplies electricity to nearby farms and industrial enterprises.

RUSSIA'S NUCLEAR POWER STATION

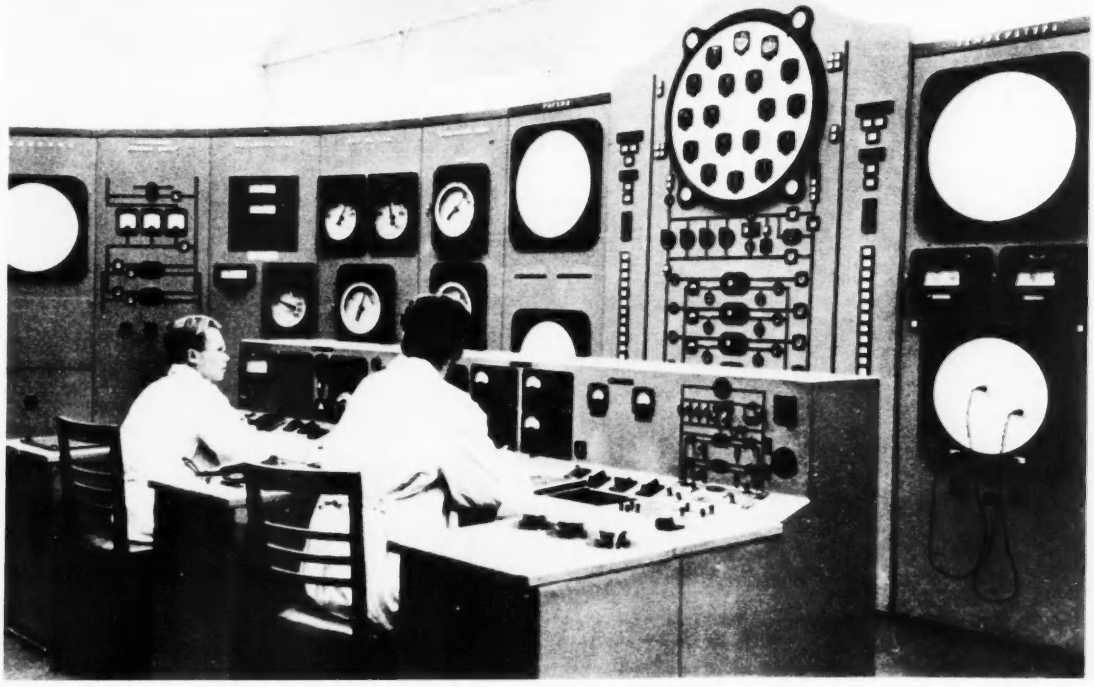
ARCHIE CLOW, D.Sc., F.R.S.E.

Several British scientists have now had the opportunity of inspecting the Russian experimental power station. In return for the visit which Russian scientists paid to Harwell just after the Geneva conference, a small party of British atomic scientists went to Russia in November. After his return, the leader of this party—Dr. B. F. J. Schonland, who is Sir John Cockcroft's deputy at Harwell—stated that "this station does not generate power at an economic cost, but was none the less of interest to us". The following description of this power station is the substance of a B.B.C. talk which Dr. Archie Clow (well known to readers as the producer responsible for "Science Survey"), who visited the atomic power station before Dr. Schonland's party, gave on the General Overseas Service.

It was my good fortune to be one of the first three British scientists to visit the Russian nuclear power station while I was in the Soviet Union in September as the guest of the Academy of Sciences. It is a modest three-story building among the trees, some 100 kilometres west of Moscow. From the outside there is absolutely nothing about it to attract one's attention: with its nearby chimney-stack, it might well be a laundry. But appearances are deceptive, and history may write it up as one of the most exciting buildings of all time.

A long drive through the quiet and lonely Russian countryside (Moscow ends quite abruptly) brought us to the new township that has grown up round the station. We were met on the steps of the workers' club by the Assistant Director and our visit began with the screening of a special film (with English, or shall I say Anglo-American, sound track). It explained, simply but admirably, what nuclear energy is, how the reactor operates, how the energy released is carried away by water at 270°C to heat exchangers, which in turn pass steam to the nearby quite small conventional electricity generating station.

No one pretends that this station, with its output of 5000 kilowatts contributes much to the Soviet's need for power. It is a pilot plant, an experiment, and a source of neutrons that can be, and are being, used for nuclear research.



The central control panel of the experimental power reactor.

Having seen the film we drove the short distance to the laundry-like reactor-house. Once inside one realised that this is no ordinary building. Like an iceberg, most of what matters is out of sight down below. Unlike any of the atomic piles at Harwell that I've seen, which tower up from floor-level, the Russian reactor starts at floor-level and works down towards, what used to be called, the nether regions. Its top is flush with the floor of a bleak and aseptic-looking hall. A twenty-foot disc of cast-iron and concrete marks the top of the reactor which contains some 130 rods of enriched uranium. A bunch of electric cables disappears into its centre, the cables that operate the boron carbide safety devices that shut down the reactor should anything go amiss. All is silent except for the hum of the ventilating plant, powerful and necessary for the safety of those who from time to time have to work in the hall. A Wellsian monster with three eyes protrudes from the wall opposite the reactor, the heavily protected remote control cabin from which the changing of the fuel rods is controlled. A reserve of some 50 uranium-tipped graphite rods—thirty feet long and a couple of inches across—hang at one end of the hall, and into the floor is let a tank in which about a couple of hundred used rods can be stored while they are "cooling off", a process that takes a year or so.

If the reactor hall is gaunt and austere, the rest of the building is quite the reverse. One proceeds downwards as into the engine-room of a ship: to the heat exchangers surrounded by masses of concrete (they work at 100 atmospheres): to the pumps that keep the working fluids circulating: down, down, till one is right under the reactor itself. It, of course, is hidden out of sight in its protective shield of steel, water and concrete. Round it are equally well protected laboratories with openings into the heart of the pile where, day by day, an ounce of uranium is being transformed into heat which in turn is converted into electricity.

Having explored the ancillary equipment to its very foundation we returned to the surface and went to the control room from which the whole plant is supervised, and whose complexity reveals the extent to which each stage of the process is monitored in the interests of absolute safety. An examination of the day's records revealed an impressive steadiness of output, but to demonstrate that it could easily be altered, one of the control engineers pulled out (or pushed in . . . I forget which) one of the control rods, and in due course we could see the record of the tiny fluctuation in output caused by the presence of the first British scientists ever to visit the Russian nuclear power station.

CALANUS: FOOD OF THE HERRING

PROF. C. M. YONGE, F.R.S.

Bishop Gunnerus of Nideros, now Trondheim, was a naturalist as well as a divine. In 1767 he found the sea in Finmark, the northern region of Norway, to be full of small animals which three years later he described and named *Monoculus finmarchicus*. He had made a momentous discovery. This small creature proved to be one of the commonest of all animals and was the first to be described of the group of crustaceans later named copepods. These are the most important members of the surface-dwelling plankton of both the sea and freshwaters and represent a link between the microscopic members of the plant plankton on which they feed and larger animals, fish and even whalebone whales, which feed upon them.

The importance now attained by the minute, shrimp-like animal described by Gunnerus and now known as *Calanus finmarchicus* (Gunnerus) is revealed in the new monograph by Dr. Sheina M. Marshall and Dr. A. P. Orr of the Marine Station of the Scottish Marine Biological Association at Millport in the Firth of Clyde. This book, entitled *The Biology of a Marine Copepod*, and published by Oliver & Boyd, summarises all that has been written about this animal, concerning its distribution, structure, development and growth, about how it feeds, respires and moves, and about its parasites and its place in the economy of marine life. Among the long list of over 270 references to scientific papers a major place is taken by those of the two authors whose prime subject of research *Calanus* has been for some thirty years and on which they continue to work with undiminished enthusiasm. So much still remains to be discovered about even the smallest of animals while the obscure depths and vast extent of the sea increase the difficulties while adding to the fascination of research.

That so common an animal should remain undescribed until less than 200 years ago is doubtless due to its small size. The adults are only between 1/5th and 1/10th of an inch long so that structure cannot be seen without some means of magnification. It was with the aid of "Cuf's magnifying glass" that Gunnerus produced the sketches reproduced in Fig. 2. His description, as translated by Prof. Hans Brattstrom of Bergen, is worthy of quotation . . . "When out of the water they looked rather shapeless, but when one observed them in their elements, especially so long as they were alive, one was able to see that they had an oblong body like a prawn, equipped with two antennae, at least as long as the body, and a rather short tail, and when observed very carefully, one could see that it was cleft at the end; but feet could hardly be seen. It swam very rapidly, straight forward as well as up and down."

The magnifying glass revealed the feet, "four pairs of forelegs, consisting of three to four bigger joints" while "on the posterior part of the body five annuli were observed, one for each pair of hind legs". As for the rest of animal, "Each half of the cleft tail was constructed like a fish fin and consisted of rays, which were connected by membranes. The snout was stumpy. . . . Not the slightest indication of eyes or mouth was observed however carefully one looked for them with the magnifying glass. The body was very transparent. shining, smooth, reddish and furnished with a skin like that of the prawns and the sea-flies but much thinner . . ."

Gunnerus placed this small animal among the wingless insects—in one of the genera established by Linnaeus, then at the height of his powers. Later one English zoologist, Thomas Pennant, separated the crustaceans from the insects while another, William Leach, was responsible for the generic name *Calanus*. Why Leach, a highly eccentric person, chose this name is obscure, the original Calanus being a Jain ascetic who followed Alexander the Great from India to Bagdad where, illness rendering life worthless, he walked living into his funeral pyre!

More recent and very detailed examination of *Calanus finmarchicus* has revealed the presence of two "forms", a matter of obvious significance when it was discovered that one lives in warmer waters than the other. The true *C. finmarchicus* is the northern, cold water form; the other, known as *C. helgolandicus*, takes its place in the English Channel, for instance. Between them they cover much of the globe.

The structure of *Calanus*, shown in Fig. 3, is that characteristic of copepods. The cylindrical body carries the pair of enormous antennae noted by Bishop Gunnerus, and these are followed by the mouth-parts; behind them came the oar-like swimming feet which give the group its name. There is a gut which runs the length of the body, a single eye placed in the middle of the head and what may be termed a brain just in front of the mouth. Internally the most striking organ is a "shining bolster of oil" which extends the length of the body; indeed so oily are these animals that a layer of oil soon covers the surface of fluid in which they have been preserved. Sometimes the oil is tinted pink, so that whole swarms appear reddish in the sea. This oil comes from the plants on which these animals feed; it is doubtless a form of food reserve, and not a device for buoyancy as some have thought.

The animal shown in Fig. 3 is a female with an ovary running through much of the body; in the male the testis occupies the same position. The sperm are conveyed to the female in cylindrical containers (spermatophores) which are attached near to the reproductive opening. Consequently eggs are fertilised as they leave the body. While one female has been known to lay up to 150 eggs in twenty-four hours, the usual number is 20–60. After one set of eggs is freed there is a pause while another set ripens in the ovary; then the process is repeated. In all 200–300 eggs are usually laid by a female, although Marshall and Orr kept one *Calanus* which laid no fewer than 586 eggs over a period of seventy-four days!

FIG. 1. The larger animals in this sample of living plankton are specimens of *Calanus*. (*Electronic flash photograph by Dr. Douglas P. Wilson.*)

FIG. 2. The original drawings by Gunnerus of *Calanus*.

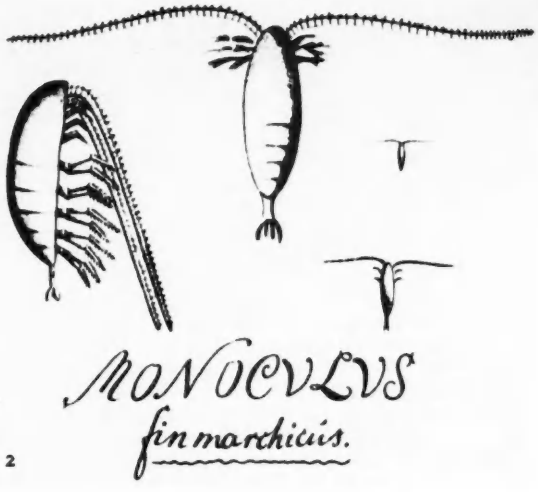


FIG. 3. Structure of an adult female *Calanus* viewed from the left side and showing the antennae and other appendages and the major internal organs.

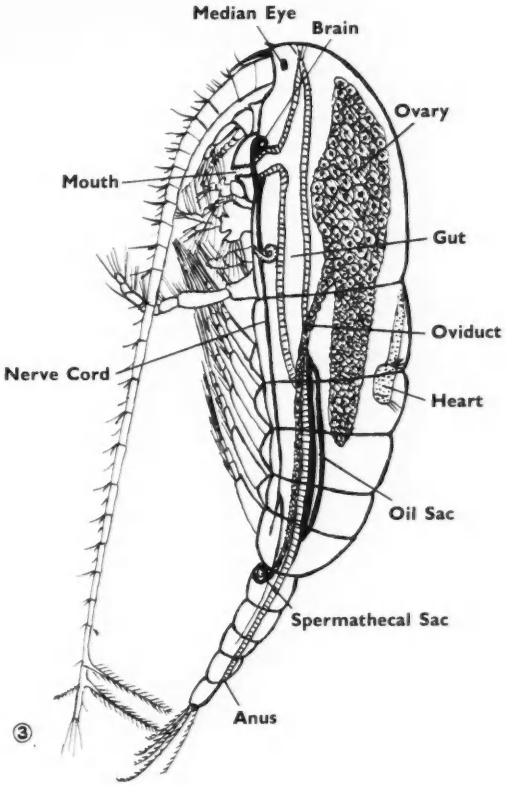
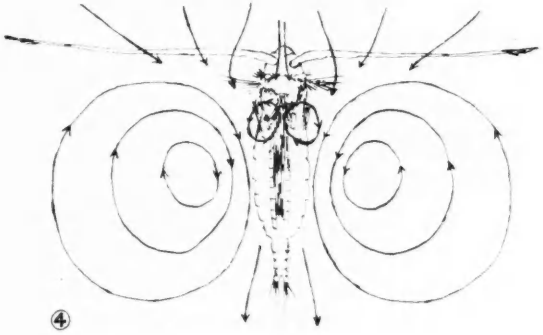


FIG. 4. Diagram of under-surface of *Calanus* showing water currents produced when swimming slowly. The feeding swirls are on either side of the mouth. (After Cannon.)



From the fertilised eggs come the next generation. Growth, as in insects, consists of a series of stages separated by moults. First there are six "nauplius" stages when the young *Calanus* is unlike the adult and has only three pairs of legs, then follow five "copepodite" stages which are like the adult into which Stage 5 eventually changes. The interesting thing, however, is that in our temperate seas there are three such generations during the course of each year, and that these broods differ from one another in size, in speed of growth and, most markedly of all, in habits.

At the beginning of the year *Calanus* is confined to deep water and practically all specimens consist of the last larval stage. During January and February these proceed to change into adults, first the males and then the females. Reproduction immediately begins and from the eggs that are laid come a new generation—the first for that year. These pass through the various stages in development and eventually become mature and start in their turn to lay eggs in late April or early May. These animals have developed faster than their parents and are smaller. Their progeny in turn develop faster still in the now warmer water becoming mature and laying eggs in June and July. Such at any rate are the dates in the Clyde sea area. This second generation is still smaller but gives rise to the largest individuals because their eggs do not reach maturity for some six months; they are the animals which spawn in January and February having survived the winter as Stage 5 copepodites which live, one might almost say hibernate, in deep water. They suffer heavy mortality so that this generation is always numerically the smallest.

Such is the sequence of events here, but in colder seas development is slowed down; off Greenland, for instance, there is but one generation annually. Then how do arctic seas support their enormous stocks of *Calanus*? A possible explanation is provided by the discovery of Marshall and Orr that the number of eggs laid is controlled by the food supply. Starve female *Calanus* and they stop laying eggs, feed them and they resume. Such experiments, moreover, provide a means for determining the food value of the various diatoms, flagellates and other plants of the plankton. Feeding with pure cultures of some of these was followed by egg production, but not with others which appear valueless as food. In the Arctic there is such vast summer production of diatoms that all female *Calanus* should be well fed and produce so many eggs that the population is maintained despite the inroads of predators and the inevitable losses of winter.

The precise mode of feeding has led to some controversy. As *Calanus* move slowly through the water—they may also leap by sudden movements of the long antennae—a swirl is created on either side of the body (Fig. 4) which in turn sets up a smaller feeding swirl around the feeding appendages, small but elaborate structures covered with fine hairs. By this means water is drawn in and the fine plant plankton filtered out and passed to the mouth. The process is elaborate, demanding co-ordination of many structures. Occasionally *Calanus* rejects the, possibly unsuitable, particles so collected and they may also pursue and capture larger food masses.

Mention must now be made of the vexed matter of vertical migration. Many planktonic organisms move up and down, largely it appears in response to the stimulus of light, making what are called diurnal migrations. No animal has been more studied in this connexion than *Calanus* but final conclusions still elude us. Conditions certainly differ in different regions, probably having to do with temperature. In temperate regions successive generations behave differently. We have already seen that in the Clyde area *Calanus* spends the winter at some depth and largely as Stage 5 copepodites. Such animals show no vertical migration but after moulting into adults the females (but not the males) make these movements, migrating surfacewards by night and then move deeper in the daytime. But the succeeding generation behaves very differently, living almost entirely at the surface. With the transition to the next brood *Calanus* leaves the surface only returning to it by night. The diverse habits of the three broods are reflected in their spawning behaviour. The females that live at the surface lay eggs throughout day and night; those that live deeper spawn only at night when they are nearest the surface. Finally, to complicate matters further there are occasional years when *Calanus* fail to appear in the surface waters even in May and June!

Calanus is of great, often of supreme, importance in the lives of many other animals; it forms an essential link in many food chains in the sea. Pelagic fishes such as herring, and even bottom-living fish in shallow water (e.g. sand eels), consume enormous quantities. Only one week after hatching, herring (then about half an inch long) take the early stages of *Calanus,* but adults are eaten after the herring grow to over one and a half inches. An average of some 2000 *Calanus* have been taken from the stomachs of herring six inches long in the Clyde area.

At one time, herring were thought to strain water passively through their gills and collect plankton on the projecting horny "rakers". But this is certainly not so for *Calanus,* the herring see their prey and, turning on their sides to do so, capture them as individuals, one by one. For this reason feeding is almost entirely confined to day-time.

In the Arctic, *Calanus* is a major food for whales, especially for the large Sei Whale where the fringes of the whale-bone plates that hang down from the roof of the mouth are so fine that they can strain these minute animals out of the water that pours in through the enormous mouth. The size of the whales and the incalculable abundance of herring are in themselves some indication of the numbers of *Calanus* and of their food value. There have from time to time been suggestions that *Calanus* and other planktonic animals should be collected for use as human food or for feeding domestic animals. But it would be difficult to locate the dense patches which alone would be worth collecting, and undoubtedly it is better for us to leave the herring and the whales to collect and digest the plankton for us.

FIG. 1. Glaciological studies will be carried out all over the world during the International Geophysical Year, particular importance being attached to glaciers on the maritime fringes of the Antarctic continent, of which the Depot Glacier in Graham Land shown here is a good example. (*Photo: F.I.D.S.*)

THE INTERNATIONAL GEOPHYSICAL YEAR

PROF. A. C. B. LOVELL, F.R.S.

The physical forces which influence the earth have always provided an attractive and important avenue for scientific research. A scientist engaged in the study of meteorology, the oceans, or the ionised regions of the upper atmosphere is faced immediately with the problem of co-ordinating his results with those from other parts of the earth's surface. The difficulties are considerable, especially when the polar regions are involved. Because of the important influence which these regions exert on the world's weather, the earth's magnetism and the aurora, two sets of international expeditions were organised to the north polar regions—in 1882–3 and 1932–3. The results obtained were of great importance and have profoundly influenced the development of ionospheric investigations and world radio communications.

The extremely rapid developments in geophysics and associated subjects since 1945 led many scientists to the belief that the time was appropriate for a third international venture. The International Council of Scientific Unions (ICSU) decided in 1951 to appoint a sub-committee—Comité Spécial de l'Année Géophysique Internationale (CSAGI)—to plan this third venture on a world-wide scale.

Many of the terrestrial phenomena involved are associated in some way with events on the sun. The sun is the prime source of energy for the circulation of the atmosphere and the maintenance of ocean currents; it is the controlling influence on the ionosphere and is responsible for magnetic storms and aurorae. Although the interrelationships are little understood it is known that they are affected by sunspot activity. Magnetic storms increase as sunspot activity increases, and the frequency of occurrence of the aurora is closely related to it; again, fade-outs in long-distance radio communication are associated with solar flares. Sunspot activity follows a cycle, the period between maximum and maximum being eleven years, and it was suggested that the International Geophysical Year (IGY) should be designed to cover the year of the next maximum from July 1957 to December 1958.

The membership of CSAGI was drawn from the scientific unions concerned and each participating country was asked to prepare a national report giving its proposals for work during the IGY. In this country the Council of the Royal Society was responsible for appointing a British National Committee of the International Geophysical Year to co-operate with CSAGI. Their report, together with the national reports from other countries, was co-ordinated at a special meeting of CSAGI held in Rome in September 1954 and a world plan of observatories and stations was drawn up. At the most recent meeting of the CSAGI, held in Brussels in September 1955, it was reported that forty nations are participating in the IGY programme. The scope of the undertaking is indicated by the provisional estimate

that the total cost of this world-wide enterprise will be over £70 million.

THE ORGANISATION OF THE IGY

Although some of the apparatus will run continuously during the eighteen months of the IGY it is impossible to attain continuity throughout, particularly in those programmes involving personal observations or upper-air soundings. A Calendar of "World Days" has therefore been formulated to ensure that the greatest range of observations of all participants shall be concentrated at peak periods of lunar, solar and meteoric activity. The placing of World Days in relation to lunar phases provided an obvious starting point. There is also great current interest in the part played by meteors, particularly in ionospheric phenomena and in Dr. E. G. Bowen's theory of the relation between intense meteor showers and periods of heavy rainfall. The sun is a major controlling influence on many of the phenomena to be studied, and during the IGY there is a total eclipse on October 23, 1957 (in which the core of umbra touches the earth for a very short time in the southern hemisphere), an annular eclipse on April 19, 1958, and a second total eclipse on October 12, 1958, in the southern hemisphere. These are all predictable, but the occurrence of sunspot groups and flares cannot be predicted in advance. In view of these and many other considerations, the calendar has been drawn up so that it provides for the following items:

(*a*) *The Regular World Days* (*RWD*) limited to three or four per month *predictable in advance,* and allocated as follows: (i) Two days each month at new moon; (ii) one day near the quarter moon, with the exact date chosen to coincide with major meteor activity; (iii) additional days of unusual meteor activity; (iv) additional days to prevent the interval between RWDs from exceeding three weeks.

(*b*) *Special World Intervals* (*SWI*). When the state of the sun is such that, in the judgment of experienced forecasting centres, magnetic, auroral and ionospheric disturbances are probable, Special World Intervals, expected to average four days each month, will be announced. These will be preceded by an "Alert" which will indicate to those responsible for special observations that a SWI may be declared within four to six days. The Radio Warning Service of the Central Radio Propagation Laboratory of Virginia, U.S.A. will be the world warning agency, assisted by the Japanese and French warning centres; the latter is to act as co-ordinator for the European forecasting groups. A comprehensive system of radio and telegraphic networks will be involved in the dissemination of the Alerts and the subsequent information.

(*c*) *World Meteorological Intervals* (*WMI*). There will be six world meteorological intervals (WMI) of ten consecutive days each for certain specialised observations. These are chosen to include the RWD's of the same month, so that on three days of each WMI there will be a concentration of all forms of observation.

A detailed calendar based on this programme has been prepared; a section of this is reproduced as Table 1 on this page.

TABLE 1. PART OF THE CALENDAR OF REGULAR WORLD DAYS AND WORLD METEOROLOGICAL INTERVALS (WMI). TWO WORLD METEOROLOGICAL INTERVALS (COMPRISING TEN CONSECUTIVE DAYS) ARE SHOWN —ONE IN SEPTEMBER AND ONE IN DECEMBER.
(from *I.U.G.G. Newsletter*, March 1955).

September 1958

Sun.	Mon.	Tue.	Wed.	Thu.	Fri.	Sat.
	1	2	3	4	5	(6)
7	8	9	10	11	12	(13)
(14)	15	16	17	18	19	(20)
21	22	23	24	25	26	27
28	29	30				

October 1958

Sun.	Mon.	Tue.	Wed.	Thur.	Fri.	Sat.
			1	2	3	4
5	6	7	8	9	(10)	(11)
(12)	(13)	14	15	16	17	18
19	20	21	22	23	24	25
26	27	28	29	30	31	

November 1958

Sun.	Mon.	Tue.	Wed.	Thu.	Fri.	Sat.
						1
2	3	(4)	5	6	7	8
9	(10)	(11)	12	13	14	15
16	17	(18)	19	20	21	22
23	24	25	26	27	28	29
30						

December 1958

Sun.	Mon.	Tue.	Wed.	Thu.	Fri.	Sat.
	1	2	3	4	5	6
7	8	9	(10)	(11)	12	(13)
14	15	16	(17)	18	19	20
21	22	23	24	25	26	27
28	29	30	31			

*Regular world day (11)
Regular world day at new moon (10)
Unusual meteoric activity 8 (but not world day)
Regular world day with unusual meteoric activity (17)
Day of total eclipse (12)

*All regular world days are circled, other days of unusual meteor activity are marked for information only.

METEOROLOGY AND RELATED SUBJECTS

The extension of meteorological observations to greater altitudes and to cover more of the globe represents a major aim of the IGY plans. Data about winds, temperatures and humidity are scarce at heights of 20 kilometres, and are insufficient at all levels in the tropical regions and the southern hemisphere. Among the special problems studied will be the redistribution in the atmosphere on a global scale of momentum and energy and the large-scale influences of surface topography and friction on this. The distribution of ozone and water vapour and the interactions between the circulation in the two hemispheres will also receive special attention.

The establishment of the complex network of meteorological stations over the globe is itself a major enterprise. It involves the re-equipment with the appropriate instruments of existing stations, and the establishment of many new stations in polar regions and on

small oceanic islands, as well as the use of merchant and whaling vessels and weather ships.

These meteorological observations will probably have the most direct and immediate practical value of the whole IGY programme. They will be of enormous benefit to air navigation and the planning of routes and schedules. Another likely result will be an improvement in the long-range weather forecasts. On a wider scale it is hoped that much light will be thrown on the possibilities of artificial control of climate, of the development of arid regions, and the nature of the long-period changes in climate which may have great effects on the economy of certain countries.

World climate is influenced critically by the extent and behaviour of the earth's cover of snow and ice, and the IGY programme includes a survey of the characteristics of glaciers and snow cover in all parts of the world. The extensive survey planned for Antarctica is particularly important. The northern ice-cap covers about 1500 by 600 miles but the Antarctic ice-cap is six times larger. If even a fraction of the polar ice-cap melted, large areas of land would be inundated. The present long-term tendency for glacier retreat is accompanied by a rise in sea-level of about four inches per century. The consequent rise in temperature of the Arctic waters has already had important repercussions on the fishing industries, and the glaciological studies of the IGY are directly linked with many such practical issues. The programme includes special seismic surveys to determine the thickness of the ice and to define the geography of the underlying coast.

These observations will be closely related to the oceanographic programme which will be particularly concerned with the general circulation of water, and the short- and long-period changes in sea-level. Circulation studies involve water-sampling and measurements of temperature and current and along defined traverses at all depths, which will enlarge our understanding of the water movements which transport large amounts of heat and nutrient salts. Ocean survey vessels will also investigate the shifting of the boundary region between temperate and polar waters, the transfer of energy across the equator and the warming of the Arctic.

The sea-level investigations will be carried out with recorders which do not respond to ordinary waves and swell, but measure the changes of longer duration including tides, seasonal fluctuations, storm and seismic surges. The phenomena involved demand international study as they are related to long waves which travel through the entire ocean and with oscillations affecting whole ocean basins. This programme has a direct practical importance in terms of the unexpected sea-level changes which affect harbours and shipping, and cause coastal flooding.

THE UPPER ATMOSPHERE AND IONOSPHERE

The investigation of the ionised regions extending from about 80 to 500 kilometres above the earth's surface was in the pioneering stage on the occasion of the Second International Polar Year of 1932–3. In the intervening years the study of the morphology of the ionosphere and of the fundamental physical processes involved has occupied many scientists. The critical part which the region occupies in the sphere of world radio communications and radar navigation has added a considerable practical impetus to this work.

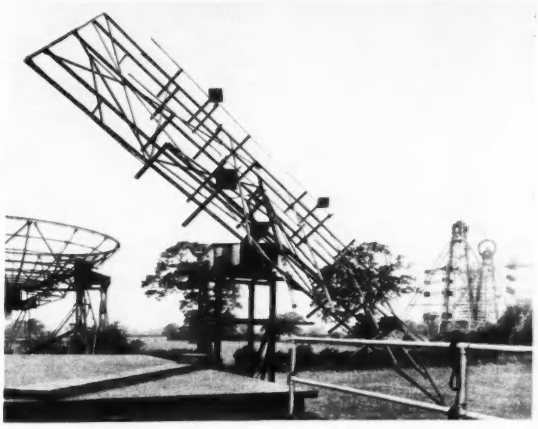


FIG. 2. Radio telescopes at Cambridge and Jodrell Bank (where this picture was taken) will be in operation. In the left foreground is part of the 30-ft. telescope which will record continuously the scintillations which occur when radiation from the radio source in Cassiopeia passes through the upper parts of the F region, an effect to be studied all over the world. In the background is the 250-ft. telescope in the course of construction; it is hoped to bring this giant instrument into use for the IGY.

The ionisation in this region is known to be under solar control, but there is no agreement as to the mechanism or even the part of the solar spectrum which is responsible. It is also known that severe disturbances in the underlying pattern coincide with sunspot groups and particularly with solar flares, when the disruption of the ionosphere is often so marked that long-distance radio communication breaks down.

At present more than fifty ionospheric stations of the conventional vertical beam, pulsed-radiation type, are working regularly throughout the world, but these can give only a sketchy outline of the world ionospheric picture. It is hoped that during the IGY at least a hundred will be in operation to give special attention to certain zones including the Antarctic, a region from which practically no ionospheric information has yet been obtained.

In addition to these fundamental measurements of ionospheric density, many related programmes are planned. For example, the extent to which radio waves at various frequencies above the critical value are absorbed in the ionised regions is a subject of increasing interest. The application to practical radio communication is obvious, and the influence of the ionosphere on the reception of extra-terrestrial radio waves from the sun and the galaxies is important in some aspects of

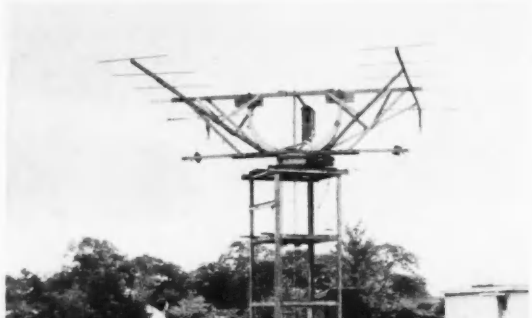


FIG. 3. A continuously rotating aerial used at Jodrell Bank in echo studies of meteors and the Aurora Borealis. A similar apparatus is to be used in the Antarctic by the Royal Society expedition, to collect data about the Aurora Australis and the meteor influx.

radio astronomy. Measurement of absorption using the emissions from the radio stars promises to be a new and powerful technique, and it is hoped that it will be explored sufficiently to supplement the existing measurements using pulse reflection methods.

Another subject which will receive considerable attention is that of ionospheric drifts; the movements of the scattering and reflecting centres within the ionosphere. In both the E and F regions a simple interpretation of the results indicates that the ion clouds must be moving at high speeds—up to hundreds of metres per second in region F, but considerably lower in region E. In many cases, the duration and speed of the drifts show diurnal and seasonal changes. There is no general agreement as to the extent to which the results must be interpreted as true movements of the ion clouds or as some electromagnetic phenomenon; nor do we know the shape, size or origin of these ion clouds.

Some of the techniques used in the study of these drifts will involve the observation of radio echoes from meteor trails. Thousands of millions of meteors enter the earth's atmosphere every day and evaporate mainly in the 80–120 kilometre region of the earth's atmosphere. As a result a transient dense column of ionisation is formed which can be recorded as a radio echo. This radio-echo technique has been used with great success in the study of the astronomy and physics of meteor phenomena. During the IGY the emphasis will be more on the connexion between these ionised meteor trails and irregular phenomena in the ionosphere, such as sporadic E ionisation. Dr. E. G. Bowen's suggestion that periods of heavy rainfall occur thirty days after the incidence of strong meteor showers adds particular interest to the correlation of the meteoric and meteorological observations.

The investigation of the aurora and airglow is another important aspect of fundamental research in the high atmosphere. The aurora is a familiar feature of the night sky to those living in high latitudes. It is generally visible only in magnetic latitudes of 60° or more, but during magnetic and ionospheric storms it becomes more widespread. The occurrence of aurorae, and the forms they take are complicated matters. Great aurorae are certainly associated with disturbances on the sun, and are believed to be a direct result of excitation in the 100-kilometre region caused by bombardment of the atmospheric atoms by the solar corpuscular streams. These great aurorae occur at times of widespread ionospheric disturbances; on the other hand in the region 20–25° from the poles the aurora can nearly always be seen, apparently independently of solar conditions.

The IGY comes at a time of maximum sunspot activity and hence of maximum frequency of occurrence of great aurorae. In the auroral belt a network of stations with automatic cameras will photograph the whole sky every five minutes throughout the night, thereby providing data on the terrestrial extent and changes of the aurora never before possible. The network of stations at lower latitudes will be less dense but will be supplemented with visual observers on land and sea, and in the air. The possibility of establishing the relationships between the occurrence of aurorae in northern and southern latitudes with reference to solar disturbances is particularly important. The straightforward photographic programme will be supported by spectrographic and other observations.

Radio-echo methods for the study of aurorae, so successfully developed during the last few years, will overcome the handicap of daylight. This technique depends on the fact that the ionisation density in the aurora is sufficient to reflect radio waves of high frequencies which otherwise penetrate the E and F regions.

In addition to the aurora there is another type of high-atmosphere luminosity known as the airglow. This is emitted all over the world, but it does not have the definite forms shown by the aurora. The airglow shows some radiations in common with the aurora, particularly certain atomic oxygen lines, but other features—such as the radiation from ionised molecules and excited atoms —are absent. In general it is too faint to be visible by eye or to be recorded by direct photography, and special photometers have been developed for its study. Already in use in France, Japan and America are some photoelectric photometers which scan the whole sky in about thirty minutes. The airglow observations made at low latitude will include the Zodiacal light.

These ionospheric and auroral phenomena are directly controlled by the sun. Observations of the state of the sun during the IGY are therefore of cardinal importance, and it is hoped to achieve continuity by extending the hours of observation at existing observatories to give an overlap of the periods of observation at stations in different longitudes. The observations will include

measurements of sunspot numbers, positions and areas, magnetic fields and polarities of sunspots, and complete data about the occurrence and life of solar flares. In addition to the conventional methods using spectro-helioscopes, a new technique of flare patrol will be used. This involves the observation of the "sudden enhancement of atmospherics" (SEAs). The increase in electron density in the D layer as a result of the flare improves the coefficient of reflection for very long radio waves, and it has been found that the consequent enhancement of atmospherics is most marked on a frequency of 27 kilocycles. This technique is particularly useful for flare patrol and flare warning under cloudy conditions.

Another part of the solar programme will involve the measurement of the radio emission from the sun. There is a steady emission from the quiet sun, but the presence of spots, flares and other disturbances gives rise to greatly enhanced and variable emission. Other features of considerable importance will be the visual and spectro-photometric observations of the corona from high-altitude stations and the measurement of the solar spectrum (particularly in the ultra-violet and soft x-ray region) before absorption takes place in the ionosphere. This latter programme which is of crucial importance to ionospheric theory can be carried out only by the rocket technique.

THE EARTH'S MAGNETISM

The universal dependence on the compass for navigation by air and sea underlines the importance of studies of the earth's magnetism, and in the realm of fundamental research the disturbance of the earth's magnetic field in relation to events on the sun is a major problem. Thus, one of the main objectives in geomagnetism will be the study of magnetic storms. These storms which disturb the earth's field so violently have long been studied but never with an adequate network of observatories, and their occurrence and nature is surrounded by obscurity. It is known that magnetic storms are most frequent when sunspots are numerous; on the other hand great storms often develop when there are no spots visible on the disc. The necessary data can be obtained by standard magnetometric equipment but the main problem is to achieve a satisfactory coverage over the earth's surface. More than a hundred magnetic stations will operate during the IGY, by far the greatest number ever in operation at the same time, particularly in the Antarctic and equatorial regions.

The rocket explorations are expected to be of particular value here. For example, magnetic recordings made in a rocket launched above the magnetic equator during a storm should establish whether the currents which cause the world-wide reduction in the earth's horizontal field are located in the ionosphere or as a ring current in outer space.

COSMIC RAYS

Cosmic ray research has been one of the most popular and fruitful fields of fundamental research during the past two decades. The outstanding success of the investigations concerned with the discovery and properties of the new fundamental particles has recently tended to obscure the importance of the more geophysical researches. A study of the intensity of cosmic rays on a world-wide basis has therefore been planned using standardised instruments: a counter telescope for the high-energy part of the spectrum, and a neutron pile monitor for the low-energy region. Since the paths of cosmic rays are governed by magnetic fields, a most important part of these investigations will be the study of the latitude effect of intensity variations with time, and of any changes in cosmic ray intensity associated with flares and other unusual events on the solar disc.

Although the main emphasis will be on such geomagnetic, aeronomic and solar problems, it is also hoped that many more specialised programmes will be carried out. These include the determination of the composition and energy spectrum of cosmic rays as a function of time, determination of the momentum spectrum (this will require high-altitude observations with balloons and rockets) investigation of the heavy particle component, and the latitude effect of secondary components.

The results should shed light on the mechanism by which such high-energy particles are produced in the universe.

LONGITUDES AND LATITUDES

The IGY programme includes world-wide determination of latitude and longitude. An annual variation in observed latitudes occurs because seasonal displacements of large air masses tilt the earth's axis slightly. A seasonal variation in longitude is associated with a variation in the rate of rotation of the earth. The programme should enable these changes to be co-ordinated more closely with the meteorological data, and may well lead to more accurate short-term predictions of longitude changes, bearing directly on the practical problem of time-signal accuracy, determination of irregularities of the earth's rotation and improvement of star catalogues. A related programme for the precise study of the times of reception of radio signals on various frequencies will yield information about the speed of propagation of radio waves around the earth and its relation to ionospheric conditions.

Another programme of great interest will be concerned with the correlation of the various geodetic networks covering the world. This will be done by frequent photography of the moon against the stellar background from about twenty well-distributed observatories. At present the accepted extrapolations linking the separate geodetic networks can be in error by as much as 200–300 feet, while the position of some islands is uncertain by as much as a mile.

THE USE OF ROCKETS

The technique of upper atmospheric exploration by the use of rockets is undoubtedly the outstanding technical advance distinguishing the IGY from its predecessors. The possibility of investigating the solar spectrum before it is absorbed in the ionosphere

FIG. 4. The sealing ship M.V. *Tottan* of 540 tons sailed from Southampton on November 22. It carried the ten men led by Surgeon Lieut.-Commander David Dalgleish, R.N., who form the advance party of the Royal Society's IGY Antarctic expedition. The aim is to establish a research station in the Vahsel Bay region (78°S, 35°W). The three scientists in the advance party are Major G. E. Watson, R.E.M.E., an electronic engineer loaned by the War Office, Dr. Stanley Evans, a radio-astronomer from Jodrell Bank, and Mr. D. W. S. Limbert of the Meteorological Office, Harrow. Their activities will include surface meteorological measurements, ionospheric research, auroral studies, measurements of atmospheric ozone and glaciological observations. The expedition has an all-sky camera which will photograph the Aurora Australis.

is an outstanding example of a measurement which can only be made by instruments carried above the ionosphere, and one which would have great effects on ionospheric theory. Another example is the investigation of the magnetic fields in and above the ionosphere, particularly during solar flares and great magnetic storms.

This type of rocket research demands large and expensive installations, and most of the results so far available come from the United States launchings in New Mexico. During the last few years, however, American scientists have developed the cheaper "Rockoon", a much smaller rocket, capable of carrying loads of 15 kilograms to 100 kilometres, and carried by a balloon to a height of about 27 kilometres before launching. The larger rockets (e.g. the U.S. "Aerobee", the French "Véronique") can carry 50–75 kilograms to several hundred kilometres. The Rockoons can be used for the exploration of the high atmosphere and the lower regions of the ionosphere, whereas the Aerobees can penetrate through the ionosphere. The programmes to be carried out with the two types of rocket are therefore distinct.

During the IGY the United States plan to fire about a hundred small rockets from various places including the Arctic and Antarctic primarily for the study of solar ultra-violet and x-radiation, especially during solar flares, cosmic ray intensity measurements, the observation of auroral particles and the airglow, and for the determination of densities, pressures and temperatures in the high atmosphere and of the geomagnetic field in the lower ionosphere. Plans to fire about thirty-six rockets (Aerobees) from the American continent are also in hand, enabling measurements to be made within or above the ionospheric regions.

It seems likely that the United States will make the largest contribution to the rocket programme, although in order to extend the geophysical coverage CSAGI has urged other countries to participate wherever possible. It is therefore likely that the number of launchings will greatly exceed those mentioned above. It is known that France intends to launch twelve rockets (Véroniques) from the Sahara during the IGY, and Britain will also join in the programme. U.S.S.R. plans have not yet been announced.

The chief drawback from which the rocket programme suffers is the limited time for which they can be in flight, and the difficulties of launching at particular times such as during the occurrence of great solar flares. The possibility of launching small rockets from aircraft in flight is now being pursued.

In view of these difficulties, thought has been given to the possibility of launching artificial satellites which can circle the earth at heights of several hundred miles for many days. The announcement President Eisenhower made at the end of July that American scientists would launch such vehicles during the IGY was front-page news. The plan appears to be to use a three-stage rocket, the first stage firing the missile about fifteen miles above the earth, and the second stage to 186 miles, where the satellite would then be launched in its orbit. The diameter of the satellite is expected to be about 20 inches and to weigh 110 pounds. In the proposed orbit the speed would be 18,000 m.p.h., and the earth would be circled in 90 minutes at an altitude of about 200 miles. No precise information has been given about the time for which the satellite will stay in this orbit, except that it may be for "days or weeks", after which it will fall and presumably burn up in the atmosphere like a meteor. The U.S.S.R. has also announced plans for satellite launchings. It is clear that a successful launching made during the IGY would be of incalculable benefit to the scientific programme.

THE ANTARCTIC PROGRAMME

The observations to be made in the Antarctic will constitute the first thorough world effort to uncover the geophysical secrets of one of the greatest land masses in the world. With an area of 6 million square miles lying almost entirely in the Antarctic Circle, Antarctica is a region of unparalleled interest in geophysics and geography. CSAGI has drawn attention to its many significant unexplored aspects, for example the influence of the great ice continent on global weather and the totally unknown nature of the ionosphere and aurora in this region. At least twenty stations should be in operation for the IGY on the Antarctic continent, with thirteen on the surrounding islands. The following nations have agreed to take part: Britain, U.S.A., U.S.S.R., France, Belgium, Australia, New Zealand, Norway, Argentina, Chile, Japan.

The main British venture will be the expedition to Vahsel Bay at the head of the Weddell Sea, at latitude 77°S., longitude 35°W. This will fill an important gap in the chain of meteorological stations running north to south through the Americas and Graham Land. This expedition will be in the zone of maximum auroral frequency, and should therefore be able to make important ionospheric and magnetic observations. The estimated cost of the equipment (much of it specially designed) and the scientific programme for this expedition is £150,000. The British Government has agreed to meet the cost of this expedition. The transport costs are to be shared with the British Trans-Antarctic expedition under Dr. V. E. Fuchs, which will start its journey across the continent from Vahsel Bay.

In this article it has been possible to sketch only the outlines of the programme which it is hoped to carry out on a world-wide basis between July 1957 and December 1958. The response of the scientists in the major countries and the support given by the various governments has exceeded all expectations. The IGY is now a vast global project, requiring a degree of co-ordination and planned effort never before attempted by the scientists of the world. The success of the enterprise should result in a revolution in our understanding of the fundamental geophysical influences on the earth, and will give practical results of immediate benefit to all peoples of the world.

THE EDUCATION OF SCIENTISTS

The British Association waged a long and vigorous campaign to get science teaching firmly established in the schools. That was a long time ago, in the heyday of Sharpey, Huxley and Tyndall, in fact. At the last meeting there was no talk about the need to introduce more science into school curricula; instead some speakers went so far as to suggest that in some schools too much time is devoted to science, and that this is damaging the student's general education.

Usually educational problems are left to the educationists, who meet as Section L of the British Association. At Bristol scientists of nearly all the different sections were discussing these problems, which indicates that there is widespread concern about certain defects in the educational system. One fault reveals itself in the inability of many science students to write good English, and it was interesting to note that after Mr. Ritchie Calder had provocatively accused scientists of illiteracy, inarticulateness and irresponsibility in his presidential address to Section X all the speakers who took part in the following discussion, with only one exception, seemed to accept that there has been a substantial decline in the standard of written English.

Mr. Ritchie Calder made several important points about science teaching in the schools. He was against too early specialisation and over-specialisation in the schools, and thought some sort of National Service, which did not waste the young person's aptitudes and usefulness, made a useful break, releasing the student from over-intensification. Only one scientist regarded National Service as a serious interruption in the embryo scientist's career—Prof. N. F. Mott, director of the Cavendish Laboratory, who expressed concern that the student capable of a brilliant research career might lose an appreciable fraction of his most creative years through such a break.

There was a very large attendance at the joint meeting of the Education and the Physics sections which discussed the education of the physicist. *Much of what was said by the four speakers and by those who participated in the following discussion was relevant to the education of scientists generally. For this reason we print below the substance of the papers by Sir Philip Morris (vice-chancellor of Bristol University) and Dr. A. W. Barton (headmaster of the City of London School). The two other speakers were Prof. N. F. Mott and Prof. F. A. Vick, physics professor at the University College of North Staffordshire.*

Prof. Mott wanted broad liberal education to flourish in the sixth form alongside specialised studies. He said the decision to read science at the university should be made as late as possible in the school career. He suggested that an ambitious university with its reputation still to make should try the experiment of setting up, with the encouragement of the Ministry of Education and Local Education Authorities, a strong intermediate course to take students who opted late for science. This would be the basis of a four-year university course. In examining entrants for this course emphasis could be put on the general paper, the assurance being given that this should play a big role in awarding scholarships. A group of university colleges could give each year an agreed number of mixed scholarships in which a candidate could take both arts and science subjects. Prof. Mott appealed for suggestions in this direction from schoolmasters.

Prof. Vick's main proposal was for a university course that would contain physics as a component but would be designed, not for the small fraction of students who would proceed to do creative research in physics, but for those who would become administrators, politicians, businessmen and industrialists. One combination he suggested was Physics, Philosophy and Economics. Such a course could form an alternative to, and stand alongside Greats and Modern Greats. He spoke of students at his college who combine physics, economics and mathematics—a good basis for an industrial career. He thought industrial scientists would have more confidence in industrialists who were trained in such a way.

SCIENCE AND A BALANCED EDUCATION

SIR PHILIP MORRIS

T. H. Huxley gave an address entitled "Science and Culture" in 1880, and it will be found in his volume of essays on Science and Education published in 1910. In it Huxley refers to the foundation of Mason's College. He refers especially to the explicit injunctions of Sir Josiah Mason "that the College shall make no provision for 'mere literary instruction and education' ".

Referring to this injunction Huxley says:

> I am not acquainted with Sir Josiah Mason's reasons for the action which he has taken; but if, as I apprehend is the case, he refers to the ordinary classical course of our schools and universities by the name of "mere literary instruction and education", I venture to offer sundry reasons of my own in support of that action.
>
> For I hold very strongly by two convictions—the first is, that neither the discipline nor the subject-matter of classical education is of such direct value to the student of physical science as to justify the expenditure of valuable time upon either; and the second is, that for the purpose of attaining real culture, an exclusively scientific education is at least as effectual as an exclusively literary education.
>
> I need hardly point out to you that these opinions, especially the latter, are diametrically opposed to those of the great majority of educated Englishmen, influenced as they are by school and university traditions.

It is important to bear in mind first, that the claims of scientific subjects to inclusion in an educational curriculum had to be fought for strenuously as recently as the early years of this century; and secondly, that those who were defending what they thought to be the best traditions of schools and universities yielded ground to scientific claims, both reluctantly and slowly. The bitternesses of the past tread hard upon our heels and discussions about the curriculum even today are frequently beggared by wounds given and received in battles long ago. I want to suggest that if progress is really to be made in solving some of the very pressing educational problems which we know to exist, we must show ourselves capable of making a fresh start and of confining ourselves to a consideration of the scope and nature of the subjects of the curriculum on the one hand, and of the abilities, potentialities and needs of those who are to be educated, on the other.

The central educational problem with which we seem to be faced has been occasioned primarily by two interrelated and interacting causes.

First, the vast increases in the map of knowledge which have been charted and partitioned into recognised subjects has been mainly scientific in nature. This increase and its nature have resulted in a markedly changed outlook on the physical universe, of man's part

in it, and also in a progressive movement in what might be called the centre of gravity of knowledge.

The second interrelated primary cause is the greatly increased significance of knowledge, especially scientific knowledge, in a complex and interdependent world of highly organised economic and social units. The foundation of the world in which we live and move is a chaotic collection of ideas and concepts arbitrarily systematised to enable us to face the requirements of the present and of the immediate future, but not themselves organised coherently. We no longer "see life as one and see it whole". In a sudden rush to enlarge man's estate and gain greater control over our physical environment we have, as it were, added substantially to the superstructure of knowledge without attending to its intellectual foundations.

Our specifically educational problem, that is to say the problem as it affects schools and universities, begins at the primary stage. The first two or three years of primary education need not detain us except to note that, in devising ways of creating a suitable environment and in laying the foundations of rudimentary skills, those who have devoted their gifts and talents to this part of the educational field have been notably successful. It is in the succeeding span of four years of junior education that the state of affairs should cause anxiety. It is not so much, or indeed at all, that the teaching profession fails to produce some impressive results, but rather that the aim and the scope and purpose and the best curriculum at this difficult stage is but dimly apprehended. This is, in part, due to a wider conception of universal education and in part to the unsolved problems of the secondary stage casting shadows on what immediately precedes it. In the public system, the break at about the age of eleven, and all that selection for varying forms of secondary schooling implies, sets the place and calls the tune. In the private preparatory schools which prepare for admission to Public Schools a problem, similar in principle, but different in terms of subject, also exists. Latin, another foreign language, and algebra and geometry in addition to arithmetic are established at an age when children in the schools of the public system are learning no foreign languages and in mathematics are still confined to arithmetic. If these differences are examined they are hard to justify; they can, however, be explained to some extent when it is remembered that both kinds of schools are deliberately seeking to meet what seem to be the requirements of the next educational stage.

FIRST SIGNS OF SPECIAL INTERESTS

The secondary stage, itself powerfully influenced by the post-secondary stage, especially by the requirements of the universities, is thus the heart of the educational problem of today. While no single definition of education can ever be satisfactory, we do not for a moment doubt that it fails in an important part of its purpose if it does not, in addition to the rudimentary skills, both give pupils the power to interpret and profit by their experience of life and living and also give them a perspective of knowledge as a whole and a freehold interest in some of its branches or subjects. This, you will probably be thinking, is not of direct relevance to the training of physicists. I maintain the contrary for what seem to be good reasons: that the interest in physics and the desire to become a physicist—or for that matter a chemist, biologist, engineer, historian or classicist—normally shows itself during the secondary stage and their genesis is partly a matter of natural bent and partly of intellectual environment and opportunity.

The problems of the secondary stage can be resolved only by those who are committed to working in this field; but they cannot solve them by themselves or unaided. The educational history of a boy or girl is a continuous story and at the secondary stage what is best for him must be thought out not only in terms of his own bent and ability, but also in relation both to what has preceded it and also to what is to follow. It is a matter of hard practical necessity that each stage of education should be a preparation for the future, but it is also of great importance that each stage should contribute to a well-rounded and balanced life for the pupil in the years it covers.

The embryo physicist will begin to show his tendencies in this direction probably in the third, fourth or fifth year of his or her secondary education. Whether a natural bent in any particular direction shows itself or not will depend upon the intellectual environment provided by school and home. It is a safe practical maxim that good ability will tend to follow the line of good opportunity and seek the more favoured pastures. Balance between the linguistic, the mathematical and the scientific would seem therefore to be a primary objective during the first four or five years of the secondary school course. But the word balance is itself ambiguous in this context because varied ability and interest in pupils are as important considerations as the arrangement of subjects and of the time allocated to each of them. It is thus more difficult to strike a balance when schools must inevitably and rightly organise pupils into groups and deploy economically and to the best advantage the various members of the teaching staff who, only to a very limited extent, are interchangeable.

Nevertheless, we should be prepared to admit that we deviate far more from a well-judged balance in the early years of secondary schooling, particularly for the more able pupils, than is necessary.

The reasons for this unsatisfactory state of affairs are many and of very different kinds, but they cannot all, taken together, be regarded as an adequate excuse because they are all under our control if we had the determination to control them and the faith on which to act rightly. Open scholarships at universities, university entrance requirements, examination syllabuses, textbooks as well as prejudices, abilities, wishes and too narrow a perspective on the present extent and state of human knowledge, all have their effects on the shaping of school courses, on criteria of pupils' progress which are frequently more devastating in their effects on the earlier than on the later years of secondary schooling.

I am going to assume that a well-balanced education

comprising religious knowledge, English, History, Geography, a foreign language, Mathematics, Science and either Music or Art or both, is the objective at which we should aim, and that to obtain our purpose we should be willing to modify anything that patently stands in the way of its achievements.

THREE KEY QUESTIONS

Three questions immediately arise. How far must Latin be regarded as the foreign language of first consideration? What is to be the scope and objective of mathematical teaching? Are physicists willing to co-operate with other scientists in reconsidering the scope and objectives of scientific teaching at this stage? I do not propose to pursue the first of these questions. It is the second and third of these questions which are, at the moment, our chief concern. The interdependence of all scientific subjects with mathematics makes the answer to these two questions more difficult. How vital is mathematical knowledge and in what precise sense is mathematical knowledge essential to progress in scientific subjects? Is it possible for an embryo scientist to make progress without specific mathematical qualifications? Must an embryo scientist develop also as an embryo mathematician or is it enough for him to master particular processes and learn a notation? I suspect that physicists, for the sake of their own subject, ought to consider these questions and in so doing not only help themselves but also help others including those who subsequently follow the humanities. As regards the third question, is it right that science should be taught, at this stage, as separate subjects? It is certainly open to question and those whose standpoint is primarily educational are entitled to be sceptical of a categorically affirmative answer. I regard it as being of the greatest educational importance that every pupil should at this stage of his or her secondary education, acquire, or at any rate learn about, the scientist's outlook on the physical universe and I place this aim above, though not necessarily in opposition to, a preliminary grounding in particular scientific subjects. Do scientists, and in particular physicists, go thus far, and if so are they willing to ensure that some time is diverted from the advancement of knowledge to ensure that there shall be a succession of fit and proper persons to take over from them and to apply scientific knowledge for the benefit of humanity?

In the later stages of secondary schooling, that is in the final two or at most three years of the full secondary school course, the problems are, in some respects, necessarily somewhat different. Inevitably particular subjects must be chosen and secondary schools must inevitably rely upon the array of subjects as it is found in universities and other places of higher learning. In one respect, however, there is a similarity. In these years also, the course followed by a particular pupil must have a balance and also be a preparation for his future.

It is fallacious to assume that a strictly relevant preparation for some particular future activity, be it in further full-time education or in employment, will of necessity constitute a reasonably balanced education. It is a fact of life that particular subjects must be chosen and that neither a good education nor a satisfactory preparation will be provided unless they are followed seriously and deeply.

The time available in a working week, the requirements of universities and the professions, the complexities of school organisation and the varied immediate needs and aspirations of particular pupils all seem to conspire together to make things most difficult. Perhaps the best form of attack is to attempt to identify some of the right questions so that all concerned might come together on a common ground of inquiry and consideration. I propose to attempt to formulate some of them.

There probably never was much that was profitable in arguments about the relative inherent importance of the subjects into which we divide knowledge for the convenience of all concerned. Scientific subjects are differentiated from each other partly by the techniques of inquiry employed and partly by the aspects of the physical universe with which they are concerned. But there is no watertight division nor are they, even in a broad sense, mutually exclusive either by way of technique or subject-matter. We should do well to accept as a working hypothesis that the conventional subjects are all of equal inherent importance and significance.

AN ALL-SCIENTIFIC CURRICULUM

If we can remove the discussion from the field of relative values, it becomes possible to ask if any scientific subject or group of scientific subjects can by themselves constitute a satisfactory curriculum in the final years of secondary schooling. To answer this question it is necessary to consider a problem to which I referred earlier, that is whether or not scientific subjects employ distinctive and different modes and processes of thought and thinking. It is also necessary to remember that while the scientific subjects are concerned with aspects of the physical universe, the subjects in the humanities are concerned mainly with the results of man's intellectual and spiritual experiences and activities. There is, or there should be, no watertight division or complete exclusiveness between the scientific subjects and the humanities. All subjects belong to the one family and all, being the products of man's questing and knowing mind, meet together on the common ground of human experience to which countless individuals over a long period of time have contributed.

If it is the function of the final years of secondary schooling to ensure that there is some depth of study involved, so that techniques are acquired as well as a genuine foothold in some branch or branches of knowledge, how many subjects should an embryo physicist study at this level at this stage of his education? The present conventional answer at the moment is inclined to be either that he should study in this manner physics and mathematics—or physics, mathematics and chemistry. Which of these two answers is given is not so important as to add that the load imposed should be tolerable to teacher and pupil and that it should be consistent not only with the good teaching of pupils as well

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as the good training in techniques, but also that time and energy should be left available for the pursuit of other interests which the pupil possesses.

We might adopt the hypothesis that the vast majority have and are going to continue to have in after life, intellectual interests outside their particular specialisms. On such a basis we could face afresh how best to employ the third of school time which, in final years of secondary schooling, should be set aside for their cultivation.

But someone will certainly say that these complications are unnecessary. They will claim explicitly, as many humanists do, implicitly, that a complete education can be provided by choosing any subject or group of subjects all to be studied to the same level. I would concede that this might be the case in the hands of imaginative teachers who were deliberately aiming to provide for all pupils a full range of spiritual, emotional, social, political and aesthetic experience. But would it be wise and prudent to make the attempt. Pupils throughout their secondary school need a variety of personalities and standpoints and their needs are as varied as their interest, outside their advanced level subjects, is difficult to catch. Would it not be better for all scientists to persuade their pupils of the very great importance of the development and nourishment of interests outside those involved in advanced subjects and leave in more competent hands the task of satisfying the need, and themselves be willing to find ways and means of doing the like for pupils whose advanced subjects are in the humanities.

THE NEED FOR RADICAL RETHINKING

You will all say, especially those who teach sixth forms, either that to arrange for one-third of the time to be taken *à la carte* is impracticable or that it would involve a radical rethinking of sixth form organisation. Nevertheless the attempt should be made and it would at least mean an escape from the frustrating and harmful tendency to think that the study of particular advanced subjects has damaging effects which must be rectified and redressed by the therapeutic values of some other particular subject. In our preoccupation with subjects and educational problems what shall it profit us if we forget that good training in a subject and good teaching in a subject are not co-extensive or co-terminus. Even able and industrious pupils of all ages must be cajoled into learning, given confidence and in a word, inspired. The human relationships between teacher and taught which acknowledge no boundaries of subject or speciality continue to be the stuff of education and without which efficient training is more difficult and infinitely less valuable.

I have left till last the university and post-secondary stages. There are one or two points in connexion with the university stage which I would like to take this opportunity of mentioning. If there is anything in this general contribution of mine, two things necessarily follow; first that as knowledge advances and the number of subjects increases the secondary school cannot increase the load they assume *pari passu* in circumstances of increasing complication and secondly that almost all I have been trying to say of the final years of secondary schooling applies with necessary modifications to the post-secondary stage. Schools and universities ought to find and establish new and more effective techniques of co-operation which should issue in really serious consideration of what is peculiar to each stage as well as of those things which are interrelated and common. No one can be anything but seriously disturbed at our failure at this time, but it would be wrong either to be surprised at it or dismayed by it.

* * *

The advancement of science, and the rapid application of scientific knowledge, has not only transformed our environment but in the narrow field of education has transformed also our educational problems, first by so directly influencing the broadening of education opportunity and secondly by causing and continuing to cause new problems of curricula both in schools and universities, and thirdly in presenting a new situation as regards the relations between them.

In scientific subjects the natural desire to take the shortest and the most direct route to the advancing boundaries of knowledge catches the imagination as surely as does the natural desire to conquer an Everest. To frustrate or discourage such desires would be the worst of remedies for what can easily lead to evil results. As has been said of the Lake district, "the main road from Ambleside by Thirlmere to Keswick does not help in an appreciation of the real form of the uplands". We must look for remedies elsewhere. Scientific teaching in universities is based upon honours or special schools and they in turn are influenced by what are thought to be the requirements of post-graduate education. In the first place, with very few exceptions, scientific courses are confined to one main and one or two subsidiary scientific subjects and in the second place "the real thing" in the way of scientific training is thought of in terms of a period of five or six years, three being undergraduate and two or three being postgraduate training by research. Is this structure right or ought it to be examined from first principles? The time to ask such a question has surely arrived when on the one hand standards in the use of language and in literary exposition of human scientific achievements are so strongly criticised by scientists and humanists alike, and when scientists can make a cogent case for lengthening undergraduate courses. There may, on careful examination, be a case for increasing the length of undergraduate courses in science from three to four years, but we should not expect such a step to do more than ease some of the difficulties. Without other improvements the heart of the problem will remain unsolved. Further, can we ignore the great influence of relying so exclusively on research as the means of postgraduate training and education?

A recent attempt will be found in the *British Journal of Applied Physics* (vol. 1, No. 1, January 1950), when I did my best suitably to inaugurate the newly founded Education Group of the Institute of Physics.

THE FUNCTION OF THE SCHOOL

DR. W. A. BARTON

In his lecture, Dr. Barton, who was a senior science master before he became headmaster of the City of London School, described and evaluated the part played by the secondary schools, chiefly the public and grammar schools, in the training of the physicist. He said:

I will begin by stressing that it is an important part, just as important as that played by the universities. For the schools have to fulfil two roles; they have to choose those who are fit to be physicists and then they have to lay the foundations of their training.

All secondary schools which have sixth forms start by giving their pupils at the age of eleven a course of general education lasting four to five years. This elementary general education will consist of English subjects—Scripture, English, History, Geography—one or more foreign languages, French, Latin, German or Greek, for example; Mathematics and Science, and some creative subjects, such as Art, Music and Woodwork.

At the end of this course, a decision is then made whether a pupil is capable of doing sixth form work and, if so, into which sixth form he shall be promoted. Here is one way in which this decision is made: all the boys in the fifth form, in which the course of elementary general education is completed, are seen by the headmaster in the middle of the summer term and are told the main subjects of each of the sixth forms, the careers to which they lead and the qualifications needed to secure admission to them, the minimum being three suitable and level passes. The pupils are then asked to state into which sixth form they wish to go, being advised individually if this is necessary; this provisional choice and the above information about the sixth forms is then sent home to their parents, who are given an opportunity to discuss the pupil's choice with the headmaster, if they wish to do so. The final decision is left to the pupil and his parents, and the school only interferes if the pupil has chosen a sixth form for which he is totally unsuitable or has perhaps chosen a soft option, or has chosen one sixth form, whereas he seems to the school better qualified for another. The pupil has been introduced to the various branches of knowledge in this course of general education; and at the end of it in most cases he knows what he wants to do and his choice usually corresponds to his abilities. Sometimes an individual pupil needs advice when he is equally good at two different branches of knowledge. To what extent should the schools try to influence a pupil's choice? The schools are not an end in themselves; they exist to provide the pursuit of knowledge and to serve the community; nor are the pupils an end in themselves; on the contrary, "he that will lose his life for my sake, shall save it" and the pupil will grow to his full stature only if he loses himself in some great cause in the service of the community.

So surely, at the present time when an abundant supply of able physicists is essential to our survival, it is the duty of the schools to make this fact known to their pupils—they will certainly not know about it unless they hear of it from their school—and to exercise reasonable persuasion to induce any boys to take up physics who have reasonable interest and ability in it.

Having decided which pupils are fit to be physicists, the school then spends the next two or three years laying the foundations of their training by giving them a course of elementary physics in the sixth form. The aim of this course should be to stimulate the pupil's curiosity, to train his critical faculty, and to develop his interest in and power to solve problems by presenting physics as a living, growing subject. I believe that this can best be achieved by finding some time in the course for presenting the principles of the subject as they develop historically. This is preferable to teaching your pupils the latest theory; first, they are not likely to be able to understand it; secondly, even if they do understand it, it gives them the impression that having learned the latest theory, there is no more to be learned; and thirdly, there is always the temptation to accept the theory as true, just because it is the latest theory, and if there is any part of it they do not understand to allow memory to be a substitute for understanding.

Surely it is better when teaching heat, for example, and the main elementary facts about heat have been established to discuss the caloric theory in some little detail and its explanation of why heat is conserved when hot and cold bodies are mixed, the pleasing way in which it accounts for change of state, the elementary fact that heat flows from hot to cold bodies and how work can be derived from heat by a process analogous to that by which work is derived from water. The pupil is then introduced to the problem set by the fact first noticed by Rumford that the chips produced in boring a cannon are hot. Where does this heat come from? And the attempts of the calorists to reconcile this fact with the conservation of heat—quite intelligent attempts, by the way—should be discussed, ending with the compelling fact found by Rumford that the source of heat obtained by this boring seemed to be inexhaustible. He seemed to have reached an impasse; and then the pupil is introduced to Joule's suggestion, which arose from his realisation that all these puzzling cases of the production of heat had one factor in common—work is being done. So the idea occurred to Joule—is heat a form of work? And he saw that, if this were true, the puzzling facts would at once be explained by an extension of the conservation of energy to include heat, or by a synthesis, as it were, of the conservation of caloric and the conservation of energy. Do not let us worry, if the pupil gets puzzled and bewildered as we take him through this discussion; anyone who tries to solve a problem or to discover some new knowledge gets bewildered sooner or later, usually sooner, and if we are to train physicists, they must be put in at the deep end of the bath and learn how to find their way out of the bewilderment of the deep end. The pupil will learn another important principle, which is perhaps too little understood, even by the physicist himself. The physicist

bases his theory not only on facts, but even more on an evaluation of facts. The calorists felt sure that the caloric theory was right, because they judged that heat lost equals heat gained was the most important fact, the most valuable fact about heat and they dismissed Rumford's hot chips as an unimportant detail; but Joule judged that the hot chips were the key facts, which would unlock the mystery of the nature of heat and he proved to be right. So by this method of presenting the subject, we are surely laying sound foundations in the training of the physicist; we are not only teaching him the difference between fact and theory, but we are teaching him how, when only a limited number of facts are known, two rival theories are possible; how to judge one against the other, how the evaluation of the facts is important in making this judgment, and how it is not a crucial experiment, as a rule, but weight of evidence which in the end, comes down in favour of one theory. This synthesis of the conservation of heat and the conservation of energy foreshadows the 20th-century synthesis of the conservation of energy and the conservation of mass due to Einstein, which is the physical principle which led to the conception of and release of atomic energy.

Practical work must also form an essential part of this course of elementary physics and it must be the right sort of practical work, in which the pupil is required to find out something himself. For example, do not ask the pupil to verify Boyle's Law for air, but rather ask him to investigate the isothermals of the gas in the apparatus and do not tell him you have put sulphur dioxide in the apparatus. Nine students out of ten will come back to say that they have verified Boyle's Law, which shows how little they know both about Boyle's Law and about deriving a truthful conclusion from their measurements; the tenth will come back with a puzzled or somewhat apprehensive expression and will tell you that there is something wrong with this gas, which shows that he can draw a conclusion from some measurements, but has not yet grasped the nature and meaning of scientific law.

IS THERE TOO MUCH SPECIALISATION?

I cannot agree that the future physicist specialises too much at school and here are my reasons. The average physicist spends eight years at a grammar school; for the first four or five years of that time, he spends two-thirds of his time on the humanities and a third on science and mathematics, and in the last three years at school he spends a quarter to a third of his time on the humanities. It he has been to a boarding school he will have spent about three-quarters of his time on the humanities for the first five years of his secondary education, and will still spend a quarter to a third of his time on the humanities in the sixth form. These are the facts in the majority of schools in this country and I submit that they refute the charge that we are specialising too much in the schools today. When I was a boy forty years ago at one of the leading day schools in the country, there was little, if any, serious study of the humanities in the science sixth, and I have no reason to think that that school was in any way exceptional. Nor can I agree that the Oxford and Cambridge scholarship examinations force too much specialisation on the schools. Again what are the facts? I have been one of four members of the Science Masters Association who have sent in comments on these papers for the last seventeen years and the Cambridge physics scholarship papers today test no more ground than those I tried to answer thirty-nine years ago—and is this right in view of the large amount of physics that has been discovered in this time? I have been helping the preparation of boys for Oxford and Cambridge scholarships for thirty years now, and the potential scholar is quite capable of answering these papers without being unduly pressed or without spending more than a reasonable time on his science. It may well be that some pupils are over-specialising in the attempt to reach the standard of these papers; but that is not the fault of the papers, but of us in the schools in trying to prepare unsuitable pupils for them, and will, I think, soon disappear now as local authorities give reasonable assistance to potential physicists to go to the university even if they are well below the standard of an open scholarship.

Again what is taught in the sixth form should be determined to some extent by the *interests* and *capacity* of the pupils. They can not only understand and enjoy Newton's rings, some elementary electrostatic theory including Gauss's theorem suitably taught and so on, but they are also interested in, have heard about and can understand some of the modern developments of physics; they can understand the explanation of the photo-electric effect and Compton effect based on the quantum theory, but they would be quite unable to grasp a discussion of the logical definition of mass.

May I suggest that university lecturers think of physics as a logical sequence of ideas, and they are inclined to draw a line somewhere in this sequence and expect the schools to teach *everything* and their pupils to know *everything* to the left of the line, leaving the universities to teach everything on the right of the line. But the human mind does not work like this; pupils at school are interested in and can learn some of the things on the right of the line, and a pupil does not learn all about what is on the left of the line by going through it once or even twice. The universities sometimes complain how little their pupils know when they come to them; as one of the few persons in this room who has taught both in a university and in a school, I would reply in all seriousness that if sixth form work in schools was taught by university lecturers, the pupils would know even less than they know now!

Isn't the point that there is bound to be some physics, which must be taught both in the schools and in the universities; there must be a good deal of common ground in the last year's work at school and the first year at the university? I believe that these complaints and difficulties could be eliminated if there was more co-operation between the universities and the schools and I urge the universities to invite the schools to discuss this problem with them.

FROM POLYPHARMACY TO CHEMOTHERAPY

E. ASHWORTH UNDERWOOD, M.A., B.Sc., M.D., D.P.H., F.L.S.

"Take millepides (in English by some called wood-lice, by others sows) and having washed them clean with a little white wine, and dried them with a linen cloth, beat them very well in a glass or marble mortar, (for they ought not to be touched with any thing of metal) and give the first time as much juice as you can by strong expression obtain from five or six of them. This juice may be given in small ale or white wine." The author of this recipe recommends it for ulcers in the breast and elsewhere. He labels it "A", which indicates, in his own words, that the remedy "hath been, either by the affirmation of the physician, or credible persons, that imparted it to me, or by trials, that I caused to be made of it, recommended as very considerable and efficacious in its kind". It is a remedy of the highest class.

The author of this choice example of therapeutic credulity and irrational and unscientific thinking was the Honourable Robert Boyle. He published this and similar "receipts" in 1688. Twenty-seven years earlier there had appeared from his pen *The Sceptical Chymist*, a book which not only ranks as one of the foundation-stones of modern chemistry but in addition constitutes a reasoned plea for the adoption of the experimental method.

How is it that such an absurd contradiction is possible in a man of such great ability and scientific integrity? The answer to this question involves the whole history of treatment as a branch of the medical art, and of pharmacology, its modern scientific basis.

This remedy is but one of many given by Boyle which included the lower animal forms, the excrements of animals and similar nauseous and ridiculous substances. In this respect medicine had changed little since the dawn of recorded history. Examples are found in the Egyptian medical papyri. For example, liver is important in the modern treatment of anaemia, but the Egyptians used it to prevent grey hair. The excrements of animals were used to relieve throbbing in the limbs.

However, in addition to such substances the list of medicinal agents used by the Ancient Egyptians included plants, resinous materials and certain minerals. Here, in effect, was the outline of the pharmacopoeias which were official until quite recent times. Among the plants used as remedies were acacia, cassia, the castor-oil plant, juniper, poppy and wormwood, and most of these six are still used. The Egyptians introduced resins such as styrax and turpentine, and they used also alum and the carbonate and bicarbonate of sodium.

The Egyptians often recommended simple remedies for certain diseases. But they sometimes gave for the same disease several remedies which were intended to be used as alternatives. The scribe, however, sometimes wrote these alternatives together in one prescription, and it has been suggested that this practice may have been the real origin of the polypharmacy—the combining of many drugs in one prescription—which became such a characteristic form of medical treatment in later ages.

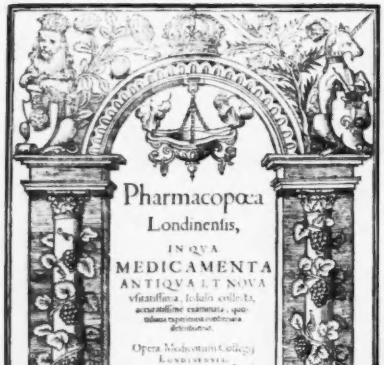
The 4th and 5th centuries B.C., which marked the Golden Age of Greek Medicine, is completely described by the word "Hippocratic", coined after the name of the great physician Hippocrates who represented all the virtues of the School. The cry of "back to Hippocrates" has frequently been heard when medicine at any time has tended to become enmeshed in a too-complex web of theories. For did not Hippocrates recommend the simplest of remedies, with emphasis on diet, air and a close study of the individual patient? Despite this, the Hippocratics had a formidable array of drugs at their command—some authorities say as many as four hundred. Five hundred years later the Graeco-Roman physician Galen had an even larger number, and he had himself as a young man travelled widely over the known world in search of new plants. But for a complete description of the medicaments used in antiquity we turn naturally to the great work which had been written in the 1st century A.D., nearly a hundred years before Galen was born. This was the treatise on drugs —the "materia medica"—which was written by Dioscorides, and which in manuscript and printed form was used for sixteen centuries.

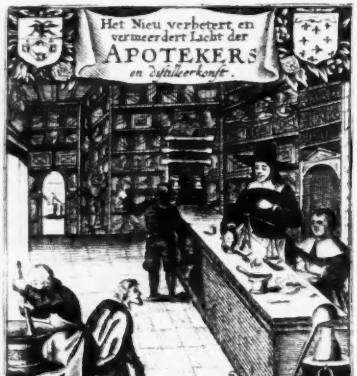
DIOSCORIDES

The *Materia medica* of Dioscorides describes about 960 substances used in medicine, of which the majority are plants. Much of the interest which the casual viewer finds today in a good manuscript of Dioscorides is centred on the illustrations of plants. Derived ultimately from 1st century originals, these illustrations often give remarkably clear conceptions of the plants themselves. They were far in advance of the illustrations which were common in the Middle Ages, and were not surpassed until after 1530. Despite its enormously long period of active use, the book was not translated into English until 1655, and the translation had to wait for nearly three hundred years before it was printed. The book has, therefore, in its history been contemporary with three landmarks in the development of therapeutics. On its first appearance in manuscript it marked the zenith of ancient therapeutics; the translation was made at a period when the new "chemical" remedies were being introduced; and the translation was published about the same time as the discovery of the sulphonamides and the antibiotics.

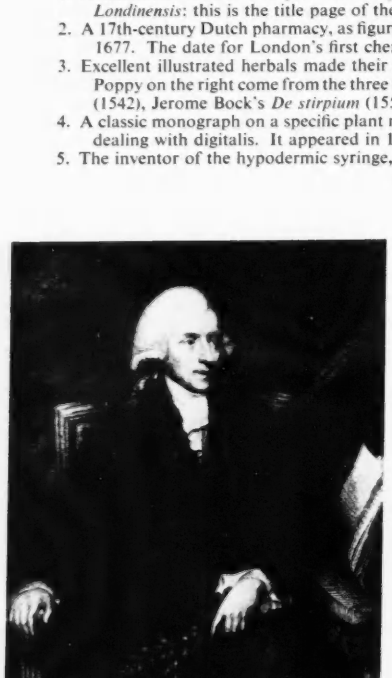
The Arabian physicians, who kept alight the torch of Greek Medicine during the Middle Ages, made advances in the methods of preparation of drugs, and they introduced a number of new drugs, such as camphor, rhubarb and senna, from Persia and India. The practice of polypharmacy certainly increased during this period.

The Renaissance saw the emergence of a refinement in the identification of plants which were of medical





1. A landmark in the history of British pharmacy was the publication of the *Pharmacopoeia Londinensis*: this is the title page of the first edition, 1618
2. A 17th-century Dutch pharmacy, as figured on the title page of *Pharmacia Galenica et Chymica*, 1677. The date for London's first chemist's shop was 1345.
3. Excellent illustrated herbals made their appearance in the 16th century. The pictures of the Poppy on the right come from the three following works: Leonhart Fuchs's *De historia stirpium* (1542), Jerome Bock's *De stirpium* (1552), Otto von Brunfels's *Herbarium* (1536–40).
4. A classic monograph on a specific plant remedy was the work by William Withering(1741–99), dealing with digitalis. It appeared in 1785.
5. The inventor of the hypodermic syringe, Alexander Wood.



importance, and it also saw the growth of some fundamentally new ideas. The refinement was due to the publication in Germany of four new herbals in the twenty years following 1530. In these herbals the excellent descriptions of the plants, and the introduction of illustrations of a standard which was quite new, gave a new impetus to scientific botany and provided medicine with a useful ally. The new ideas were born in the fertile brain of Paracelsus, whose stormy life has been the subject of much speculation. Few men in medicine have aroused so much controversy as he did. His rambling contributions to the literature are full of mysticism and of boastful and far-fetched statements. Despite this he made definite advances, such as the introduction of the metals mercury and antimony into medicine. Paracelsus realised that the action of medicines prepared from plants was due to some active constituents, and he introduced new methods of extracting these "quintessences", as he called them, by the preparation of tinctures, essences and extracts. By his methods of distillation, maceration, and other processes, he believed that he had created some new substances which were supposed to be much more effective in treatment. Nevertheless, it was long before the new chemical remedies established themselves, and the battle was not won until after Boyle had published *The Sceptical Chymist*.

The reason why Boyle could write a great book on a purely scientific subject and in another work express the utmost credulity regarding the efficacy of medicines was that in his time medicine was far from becoming a science. His unassuming book on medicines was therefore an expression of the primitive state of therapeutics during his age. In order to understand the action of a certain drug on the course of a certain disease, we must have precise knowledge of the changes which it produces in the body afflicted with that disease. This presupposes that we know the changes which the disease itself has produced in the body. But this was knowledge which could not possibly be available in Boyle's time. Even at that late period the practice of medicine was still carried out by men who walked in the leading-strings of the long-dead Galen. In anatomy his influence was gradually being cast off; but medical theory was still dominated by Galen's "humoral pathology", which was fundamentally wrong, and which moreover stultified all possibility of any scientific advance. The literature of the age of the First Elizabeth is spangled with charming metaphors derived from this outworn theory—which was still very alive at that period. It was not until the time of Morgagni and John Hunter and Matthew Baillie, a century after Boyle, that the foundations of a new pathology, based on the solid tissues, began to be laid. The keystone of the new approach was truly laid by the publication of Virchow's *Cellular Pathology* in 1858, when the site of the fundamental changes in disease was finally shown to be the individual cell.

"THERAPY MUST BECOME A SCIENCE"

And what did Virchow at that late date think of those who tried to treat disease in a scientific spirit? Here is his illuminating and far from flattering opinion: "Therapy is in an empiric stage, practised by practical doctors and clinicians, and it is as a result of an alliance with physiology that it must become a science, which today it is not."

In this phrase Virchow expressed the second necessary criterion before a drug could be effectively used in the treatment of a certain disease. The precise manner in which the drug produces its effects must be known, and this implies a scientific study of its action on the normal body. This meant an advanced knowledge of physiology, so that the action of the drug could be studied experimentally in animals. Although physiology had made much progress during the latter half of the 19th century, this period was dominated at first by Virchow's cellular pathology and later by the rise of bacteriology. Although two great French physiologists, Magendie and Claude Bernard, two distinguished German professors, and a celebrated English physician had begun to study drugs in this way, there had been no general advance. The first pharmacological laboratory in the United States was founded in 1890, and the first in England in 1905. During the last fifty years, therefore, pharmacology has made enormous advances under the guidance of men such as Schmiedeberg, Abel, Arthur Cushny and A. J. Clark. Until these were made there was no scientific method of investigating the action of a drug on normal organs and tissues, and knowledge of its action in the diseased individual was purely empirical.

Any attempt to thread a path through the maze of successive theories and practices which led to the simplification and improvement of medical treatment is far beyond the scope of this article, but it will nevertheless be necessary to indicate a few of the important milestones on the way. First came the introduction of hitherto unknown drugs from the New World in the middle of the 16th century. A century later another new drug, which was destined to influence man's happiness, economy and prosperity in peace and war, was brought to Europe from Peru. This was Jesuits' Bark (cinchona), which was early recognised as a specific remedy for malaria. Its mode of action was unknown, for the malaria parasite was not identified until the late 19th century. But the correct treatment of malaria was nevertheless clearly recognised.

The next landmark was the period in the later 18th and early 19th century when medical treatment had literally run riot. Everything was carried to extremes; patients were bled, purged and blistered to a heroic degree, and when the disease did not kill the treatment sometimes did. Such practice received a sharp rebuff when Hahnemann's system of homoeopathy became a somewhat unworthy rival in the first half of the 19th century. Hahnemann's whole system was founded on an error and a misconception, and the tiny doses which he later recommended were so ridiculously minute as to be quite powerless to have any effect at all on the organism. His utterly unscientific system, however, by its emphasis on small doses, did much to bring into disrepute the enormous doses, the giving of many drugs, and the heroic measures of his time.

Two of the great names connected with the isolation of plant alkaloids important in medicine were those of Pierre Joseph Pelletier (1788–1829), and Joseph Bienaime Caventou (1795–1877). This statue of them stood in Paris until its destruction in the last war.

The next landmark was the systematic search for the active principles of certain plants, using a technique which had been fathered by the work of Lavoisier and his successors in the Chemical Revolution. In 1806 Sertürner isolated morphine from opium. It was recognised as belonging to the class of chemical substances called the alkaloids. Within the next thirty years many other alkaloids—emetine, strychnine, atropine and quinine—had been isolated, by Pelletier and Caventou in particular, and were being manufactured in pure form, and the invention of the hypodermic syringe enabled these to be given by a route which ensured speedy action.

CHEMOTHERAPEUTIC REMEDIES

The birth of systematic bacteriology in the closing decades of the 19th century, and the successful treatment of some infectious diseases by immune sera, led to a search for drugs which would be effective in the case of those diseases in which sera could not be used. Paul Ehrlich of Frankfort was by far the most successful of such workers, and it was by his vision, his persistence and his genius that the new science of chemotherapy was founded. Ehrlich's ideal was a substance which would have a specific destructive effect on the parasites of a disease, but which would be relatively innocuous to the tissues of the host. By the early 1900's organic chemistry had given to the world a wide range of synthetic aniline dyes, and Ehrlich had worked with some of these in an attempt to cure African sleeping-sickness. By 1905 the organism of syphilis was discovered by Schaudinn and Hoffmann, and Ehrlich now turned his attention to that disease. Using an arsenic basis he began to synthesise organic arsenic compounds from it, and as each was made it was tested repeatedly in animals. The six-hundred-and-sixth compound which Ehrlich synthesised proved to be effective, and it was named salvarsan ("606"). It was the forerunner of many similar compounds used in the treatment of syphilis and trypanosomiasis.

The chemotherapeutic remedies which were synthesised were effective only against the organism of syphilis and against certain protozoal parasites. It was not until 1935 that Domagk synthesised a drug that was effective against bacterial organisms. This was sulphanilamide. A long series of these sulphonamides has now been tried out in various diseases, and they have proved generally very successful.

The latest phase in the introduction of new drugs was the development of penicillin. The destructive action on cultures of bacteria produced by the action of the mould *Penicillium notatum* was discovered and extensively investigated by Sir Alexander Fleming in 1928. Fleming did not succeed in his attempts to obtain the active substance. This proved later to be a very complex chemical and bacteriological problem, which was solved at Oxford in 1940 by Sir Howard Florey, Dr. E. Chain and their colleagues. Penicillin has revolutionised the outlook on many diseases.

The success of these modern chemotherapeutic remedies, and their manufacture on a large scale, has changed the face of medicine. The history of pharmacy is bound up with the history of many useful, curious and beautiful objects—balances, pill-cutters, drug jars —which were used by the pharmacist when pharmacy was an individual art. These things have passed or are passing. But in the realm of treatment there is still one factor which has remained but little altered through the centuries. In severe illness the psychology of the patient is altering only slowly; and when the new drug fails to cure, the patient may still turn hopefully and credulously to the remedies of his forefathers. It may be long before pharmacology evolves methods to assess the action of drugs on this subtle factor.

(An exhibition with the theme "The Story of Pharmacy" prepared by the Wellcome Historical Medical Museum from its collection, can be seen throughout this month at the Wellcome Building in Euston Road. It is open from 10 a.m. to 5 p.m. Mondays to Fridays. It contains many manuscripts, books and objects relating to the persons mentioned by Dr. Underwood who supplied the illustrations for this article from the collection of the Wellcome Historical Medical Museum, of which he is director. The picture of Alexander Wood derives from a book published by Paul B. Hoeber, New York (*Intravenous Anaesthesia*, 1944).)

INDUSTRIAL UTILISATION OF FISSION PRODUCTS

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Atomic Energy Research Establishment, Harwell

Large-scale applications are being sought very actively for the radiation from fission products now becoming available in ever-increasing quantities. To explore the industrial possibilities in this field the Atomic Energy Research Establishment at Harwell established last year a special Technological Irradiation Group within the Isotope Division. The author of this article is in charge of the chemical aspects of the new project.

Fission products will be produced on an ever-increasing scale as the programme for power generation from atomic energy gets fully into its stride. It has been announced that by 1965 power reactors producing 2000 megawatts of electricity will be installed and that each succeeding year would see the installation of a further 2000 megawatts of electrical generating capacity. If we take a figure of 20% for the efficiency of conversion of nuclear to electrical energy, 10,000 megawatts of nuclear power will be needed for the generation of 2000 megawatts of electrical power. The generation of this power will entail the consumption of $3\frac{1}{2}$ tons of uranium-235. Although the energy liberated when a uranium nucleus undergoes fission is very large, the weight of matter equivalent to this energy is almost negligible and the weight of fission products is virtually equal to that of the uranium consumed, i.e. $3\frac{1}{2}$ tons. The weight of fission products is therefore not very large. However, their radioactivity is considerable.

The amount of radioactivity is measured in terms of the *curie*. This is the amount of a radioactive substance which emits $3{\cdot}7 \times 10^{10}$ particles or rays every second and it is equivalent to the activity of a gram of radium. It can be shown that the activity available from $3\frac{1}{2}$ tons of fission products is equivalent to a steady source of 1000 million curies. This enormous figure can be compared with the total prewar supply of radium estimated at approximately 200 curies.

A large research effort is being made, both in Britain and in the United States, to find uses for the radiation from the fission products. Already discoveries of considerable interest have emerged.

For many years now, the greatest use for radiation has been its employment in radiotherapy by hospitals, but in terms of potential industrial requirements the sources used are relatively small. The amount of radioactivity required to satisfy the total radiotherapeutic demands of this country is only about 200,000 curies, and even allowing for possible exports the demand cannot be much greater than a million curies. We cannot therefore consider this use as being likely to consume any large amount of radioactive material. However, there are possibilities in other medical and biological fields.

STERILISATION

It has long been known that radiation can destroy bacteria and other organisms. In general, the higher the form of life, the easier it is to destroy with radiation. For example, doses of well over two million roentgens are required for viruses; some bacteria require about 500,000 roentgens, while insects are destroyed by doses of the order of 50,000–10,000 roentgens. Man himself can be killed with a dose of as little as 500 roentgens.*

The main virtue of radiation sterilisation is that the temperature of the irradiated material is not raised appreciably; in most cases the temperature rise is only about 2–3°C. Such "cold" sterilisation is particularly valuable for materials which are adversely affected by heat. It is unlikely that radiation sterilisation can compete with heat sterilisation in other cases, since its cost seems likely to be higher.

We know that doses of the order of a million roentgens are required for sterilisation, and it is therefore possible to determine the quantity of material which could be processed using a source of a given strength. Assuming a reasonably efficient utilisation of the radiation, one finds that a source of a million curies could deliver a dose of 10^6 roentgens to approximately 10,000 tons of material each year, at a cost of approximately a penny a pound. (This estimate is based on the assumption that the source is paid for within ten years.)

Much work has been carried out on sterilisation both in Britain and in the United States. Most of the early work has been aimed at the complete sterilisation of food with doses of a million or more roentgens. Unfortunately the treatment of food with doses of this order leads to the production of undesirable "off-flavours" and odours. The extent to which chemical changes take place in the food is very small, but the organs of taste and smell are so sensitive that they can detect these minute changes. Research has shown that removal of oxygen from the food and subsequent freezing before irradiation can reduce the undesirable effects of "cold" sterilisation.

The radiation sterilisation of food is of military interest; if a front-line soldier could be provided with fresh food with the minimum of refrigeration, the supply problem would be eased. However, a considerable amount of research will have to be carried out before the complete sterilisation of food by this method becomes a practicable proposition.

The taste and flavour objections can be overcome by

* The roentgen is the unit of radiation dosage and it is that amount of radiation which when absorbed in a gram of air causes the dissipation in that air of 83 ergs of energy.

limiting the radiation dose given to the food. Even though it is not completely sterilised, the time for which the food can be kept may be substantially increased. It has been shown in the United States that the storage life of fresh meat in a refrigerator can be increased by a *factor of five* by a radiation dose of 50,000 roentgens. This dose produced no offensive odours and flavours, although the colour of the meat was slightly affected during storage.

Very interesting effects have been observed with potatoes (Fig. 7). Sprouting can be inhibited for periods of at least eighteen months if potatoes are exposed to a radiation dose of 10,000 roentgens. The radiation damages the eyes of the potato so that they cannot grow into shoots. The satisfactory control of sprouting would mean that potatoes in good condition would be obtainable all the year round; this would be of particular advantage in the spring before the new season's crop is ready. There is no detectable odour or flavour change. The sprouting of onions is easily prevented by doses of the order of 3000 roentgens.

Irradiation of bananas seems to inhibit ripening. After thirty days' storage, the flesh of bananas which had received 150,000 roentgens was firm and of a light colour, whereas bananas which had received no radiation were soft and discoloured.

"COLD" STERILISATION OF DRUGS

Many drugs decompose when heated and therefore they cannot be sterilised by the usual process of heating with superheated steam. The only method usable at the moment is to remove the bacteria from the solution of the drug by filtration, and to carry out the subsequent operations, including the filling of vials with solution, under aseptic conditions. This procedure is costly, and has the drawback that it does not offer any certainty that all the vials will be sterile, as the possibility of chance contamination is always present. Radiation in doses of the order of a million roentgens will completely destroy all bacteria without raising the temperature of the vials, and in most cases the potency of the drug is unaffected; penicillin, streptomycin, aureomycin and terramycin have all been effectively sterilised.

Another interesting development is the sterilisation of living tissue. By this method sections of arteries can be sterilised and kept for several months, if need be, before they are used to replace one which has been damaged. Such sections behave just as well as the normal fresh material used for grafting. Bones can also be sterilised in this way and are suitable for grafting after many months of storage.

These are just a few of the many possibilities of "cold" sterilisation. Already in the United States, ointment containing heat-sensitive antiseptics is being sterilised on a commercial scale using radiation, and many other applications are now approaching the stage of commercial development.

KILLING PARASITES AND INSECT PESTS

The lethal effect of radiation has been used in the treatment of meat infected with various parasites. Infestation of pork with the nematode *Trichinella spiralis* is not common in Britain, although it is very prevalent in hot climates. Irradiation of pork with relatively low doses of radiation completely prevents the reproduction of the threadworm without in any way affecting the meat. Such treatment of pork carcasses with radiation would effectively wipe out this disease, which affects human beings who eat "measly pork".

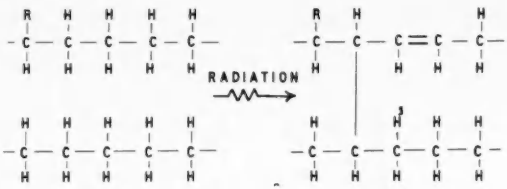

RADIATION
+ 2H2
TWO POLYETHYLENE CHAINS LYING ADJACENT TO EACH OTHER. R IS A SIDE CHAIN, POSSIBLY C4H9 BUTYL
THE TWO POLYETHYLENE CHAINS ARE NOW JOINED TOGETHER BY A CROSS LINK

FIG. 1. The effect of radiation on polythene.

The irradiation of wheat and flour has also been suggested as a means of controlling granary pests and quite recently some success has been recorded on a laboratory scale in the treatment of wood infested with the death-watch beetle.

PHYSICAL CHANGES

A considerable amount of work has been carried out on the behaviour of various polymers after exposure to radiation. Polyethylene (or "polythene") consists of a series of straight hydrocarbon chains with an occasional side chain. The effect of radiation is to cause chemical bonds to form between the chains with the result that when the temperature of a piece of irradiated polythene is raised, melting does not take place, instead the material behaves rather like a stiff jelly. At the same time, hydrogen is evolved.

With increasing amounts of radiation, all the molecules eventually join together to form a giant molecule. Fig. 1 shows how the loss of hydrogen from adjacent chains causes the molecules to join together. Occasionally a double bond is formed in the main chain.

This double bond is easily attacked by oxygen at high temperatures, and therefore it is necessary in most cases to add anti-oxidants to the polythene before irradiation. These will slow down oxidative reactions and prevent decomposition of the polymer. Polyethylene treated in this way can be used for cables operating at between 130°C and 140°C, temperatures which are well above the normal melting point of the polymer. Although the doses required to effect this change are quite large (of the order of 10^7 to 10^8 roentgens), similar effects can be produced in rubbers at lower doses. The irradiation of ordinary gum rubber produces a rudimentary vulcanisation, while ordinary vulcanised rubbers are hardened. The process of vulcanisation is very similar to the "cross linking" of polyethylene previously mentioned, although the exact detail of what happens on

irradiation is not known with any certainty. An important advantage conferred by the use of radiation as a vulcanising agent is that the high-temperature properties of various synthetic rubbers vulcanised in this way are markedly superior to those vulcanised chemically.

Some acrylate rubbers are virtually impossible to vulcanise chemically, but radiation vulcanisation can be easily carried out.

The need of the aircraft industry for special rubbers that can withstand high temperatures has led to the production of synthetic plastics containing fluorine. Although many polymers containing fluorine are broken down by radiation, cross linking takes place in others, leading to an increase in their resistance to solvents. The molecules of the polymer are more firmly bound together; this makes it much more difficult for the solvent to penetrate between them, and therefore the swelling which takes place when the polymer is immersed in certain solvents is considerably reduced. An example of this is provided by the fluorinated rubber known as FBA; the degree of swelling of irradiated FBA in fluorine-containing solvents is only a tenth of that of the untreated material.

IRRADIATED TRANSISTORS

Metals are not, in general, greatly affected by radiation. An exception is provided by germanium, which is used in transistors. The transistor depends for its functioning on defects in the germanium lattice caused by the introduction of atoms of arsenic into the metal. Similar inperfections may also be introduced by irradiating the transistor. This has the effect of reducing the cut-off time of the transistor, and therefore an irradiated transistor can switch itself on and off much more rapidly than one which has not been irradiated. This is important if the transistor is to be used in a high-speed circuit—in a digital computor, for example.

A topic on which little work has been carried out is the irradiation of catalysts. About thirty years ago it was claimed that the irradiation of a platinum catalyst with x-rays increased the percentage conversion of sulphur dioxide to sulphur trioxide. The claim was not substantiated by further experiments. It would, however, be interesting to study some of the many industrial processes relying on catalysts in order to see whether irradiation of the different catalysts involved has any significant effect.

An example of a change in physical properties brought about by irradiation is the alteration in the colour of gem stones. Diamonds can be coloured, and many interesting colour effects can be obtained with quartz.

CHEMICAL EFFECTS

Chain reactions are likely to be of major interest in a study of chemical reactions initiated by radiation. Generally the yield from a reaction in which radiation is used is expressed in terms of the *G value*: this is the number of product molecules obtained by the reaction for every 100 electron volts of energy absorbed. For non-chain reaction G values of unity are common, but for chain reactions G may be about 10,000–50,000. It is immediately obvious that the cost of using radiation per pound of product will be much less for the chain reactions than for reactions which have relatively low G values.

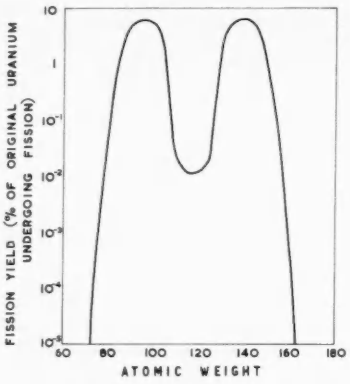
Polymerisation reactions are obviously of major interest. It was discovered quite a long time ago that alpha rays could polymerise acetylene, but only recently has it been shown that ethylene can also be polymerised using radiation. Under these conditions the polymerisation of ethylene takes place at room temperature and at pressures very little above atmospheric, whereas ordinarily pressures of over 1000 atmospheres and temperatures of 200°C are required. Varying the temperature and pressure used in the radiation process yields products with different properties, and it may be that these new types of polyethylenes will have important uses.

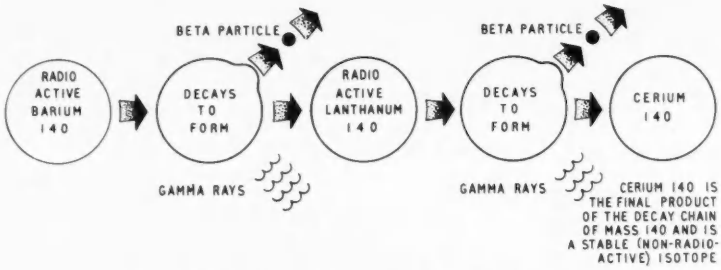
The polymerisation of N vinyl pyrollidone has received a great deal of attention. The polymer is used as a plasma substitute, and rigid specifications must be met in its manufacture; in particular the molecular weight range must be as narrow as possible. If radiation is used to initiate the polymerisation a sharper fraction is obtained than ordinarily.

Chlorination is another reaction which can be initiated by radiation. Some years ago, a large amount of work was carried out on the use of ultra-violet light. There were, however, many difficulties in its use: often the light was so strongly absorbed by the reagents that it was difficult to get a reasonable intensity throughout the solution. Transparent windows had to be arranged in the reaction vessels, and the arcs providing the light proved temperamental and were difficult to maintain. None of these objections applies to gamma radiation. It has already been shown that radiation-induced chlorination proceeds extremely rapidly and that the reaction does not always proceed in the same manner as the usual chlorination reactions.

Another possible industrial application is the use of radiation in the field of high-temperature oxidations. Oxidations are essentially chain reactions, and in general fairly high temperatures are necessary to start them. An example is the direct oxidation of benzene to phenol. A considerable amount of work was carried out on this reaction, but the process was not economically satisfactory because approximately 60% of the benzene was oxidised completely to carbon dioxide and water. It seems possible that by use of radiation, the oxidation chain might be started at a somewhat lower temperature with an increase in the efficiency of conversion of benzene into phenol. This field remains virtually unexplored.

In general, the energies used in radiation work are quite sufficient to break any chemical bond, and therefore many reactions can be initiated. It might be expected that a complex mixture of products would be formed; this, however, is not so; the molecule, in fact, breaks at the weakest point, and usually only a few products are obtained.




RADIO ACTIVE BARIUM 140
BETA PARTICLE
DECAYS TO FORM
GAMMA RAYS
RADIO ACTIVE LANTHANUM 140
BETA PARTICLE
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GAMMA RAYS
CERIUM 140
CERIUM 140 IS THE FINAL PRODUCT OF THE DECAY CHAIN OF MASS 140 AND IS A STABLE (NON-RADIO-ACTIVE) ISOTOPE

FIG. 2. (*left*) Yield curve for uranium fission products.
FIG. 3. (*above*) Radioactive decay chain whereby cerium-140 is produced from barium-140.

NATURE OF THE FISSION PRODUCTS

Having seen something of the industrial potentialities of atomic radiation, it is worth examining the nature of the radiation and also the various ways in which suitable radiation sources might be made available for industrial use.

The fission of a uranium atom does not in general result in two fragments of equal weight; in fact the probability of an unequal split may be a thousand times greater than that for an equal split. Since the uranium atom can split in a variety of ways, many different fragments, of different weights, are formed. These fragments, the majority of which are unstable, are the fission products. A large number of elements are involved, with atomic weights ranging from 72 to 162. The yield of each of these elements (expressed in terms of the number of specific atoms formed), for each 100 uranium atoms which are split, is shown in Fig. 2. It can be seen that the most likely manner of fission is into two fragments having atomic weights of 98 and 133 respectively. It is interesting to note that among the elements formed is technetium-99—the missing element eka-manganese. (Fission products are the only source of supply of this element.)

The nucleus of any atom is stable only as long as the ratio of protons to neutrons in the nucleus lies between certain limits. In the case of the fission fragments, this ratio is too low for stability and therefore an electron or beta particle is ejected. Thus the ratio is increased, and the nucleus stabilised. Often more than one electron has to be thrown off from the nucleus in order to reach stability. Even then, in many cases, the energy possessed by the nucleus may still be too high and in order to get rid of this energy a gamma ray may be emitted. An example of this radioactive decay is given in Fig. 3.

The rate at which radioactive atoms decay is expressed in terms of their "half-life": this is the time taken for half of the atoms to decay. In the case of the radioactive fission products, this time may vary from a few seconds to as long as thirty-seven years.

The fission products are formed within the uranium fuel rods in the pile, and so these rods from the pile are intensely radioactive when they are removed. We have seen how the radioactivity of the fission products decays, and use is made of this fact in atomic energy technology. The fuel rods from the pile are always stored for some time so that the radioactivity can die away and make subsequent handling rather easier. During this period the fuel rods could be used as a source of radiation for the carrying out of industrial processes. Fig. 4 shows how these rods might be used. They are mounted within a space enclosed by thick concrete walls which absorb the radiation and so protect operators working on the outside of the building. The materials to be irradiated are carried past the fuel rods on conveyor belts. A deep well of water is provided underneath the fuel rods, so that when maintenance work has to be done within the irradiation chamber the rods can be lowered down into the well; the workmen within the chamber are protected because of the shielding effect of the water. The entrance to the irradiation chamber is a labyrinth; there is no direct path by which the rays can escape. After some months the radioactivity of some of the fission products with a short half-life decreases appreciably, and the fuel rods are sent to the separation plants for processing. Here the uranium and plutonium are recovered, and the fission products appear in the waste liquors from the separation process. Most of the radioactivity dies away during the storage period, and the only remaining elements which are highly radioactive are strontium-90, caesium-137, zirconium-95 and cerium-144, with half-lives of twenty-five years, thirty-three years, sixty-five days and 290 days respectively. Because of their long half-lives strontium and caesium are extremely valuable radioactive elements for industrial use; as sources of industrial radiation they need be replaced only at very long intervals.

The two elements have quite different radiation properties, the caesium emitting principally gamma rays and the strontium giving off only beta particles. Of the two, the gamma rays from caesium are the more useful because they will penetrate more deeply. (For example, they can penetrate steel and the other metals commonly used for the construction of chemical plant.) Gases or liquids contained within reaction vessels can easily be irradiated with gamma rays merely by placing a quantity

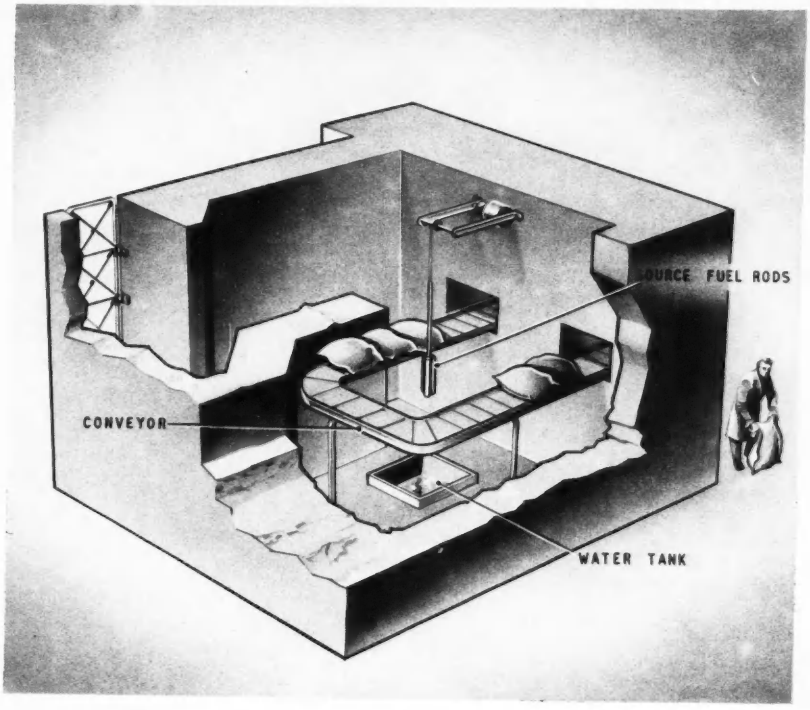

FIG. 4. ARTIST'S IMPRESSION OF AN INDUSTRIAL RADIATION UNIT USING FUEL RODS.

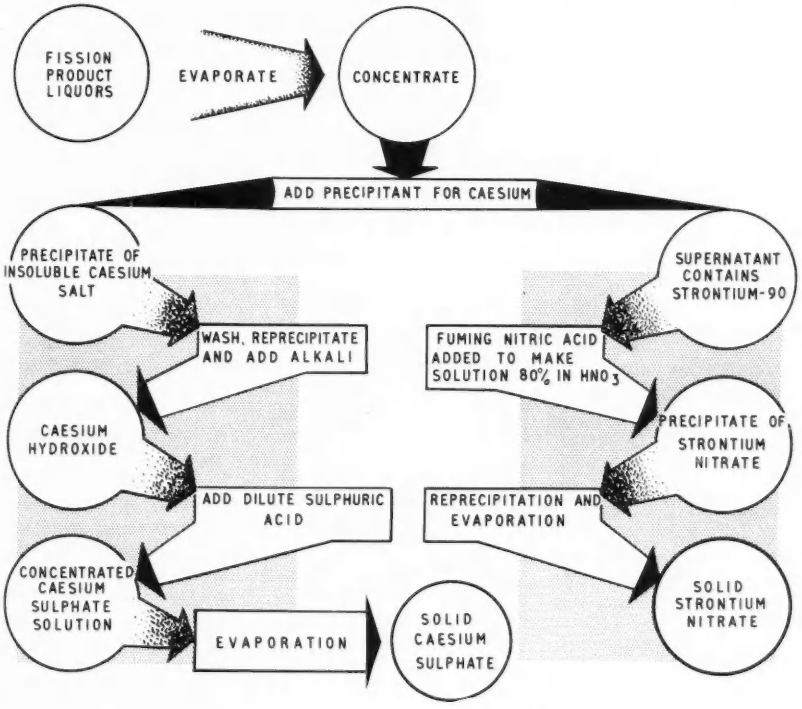

FIG. 5. FLOW SHEET FOR CAESIUM AND STRONTIUM PRODUCTION.

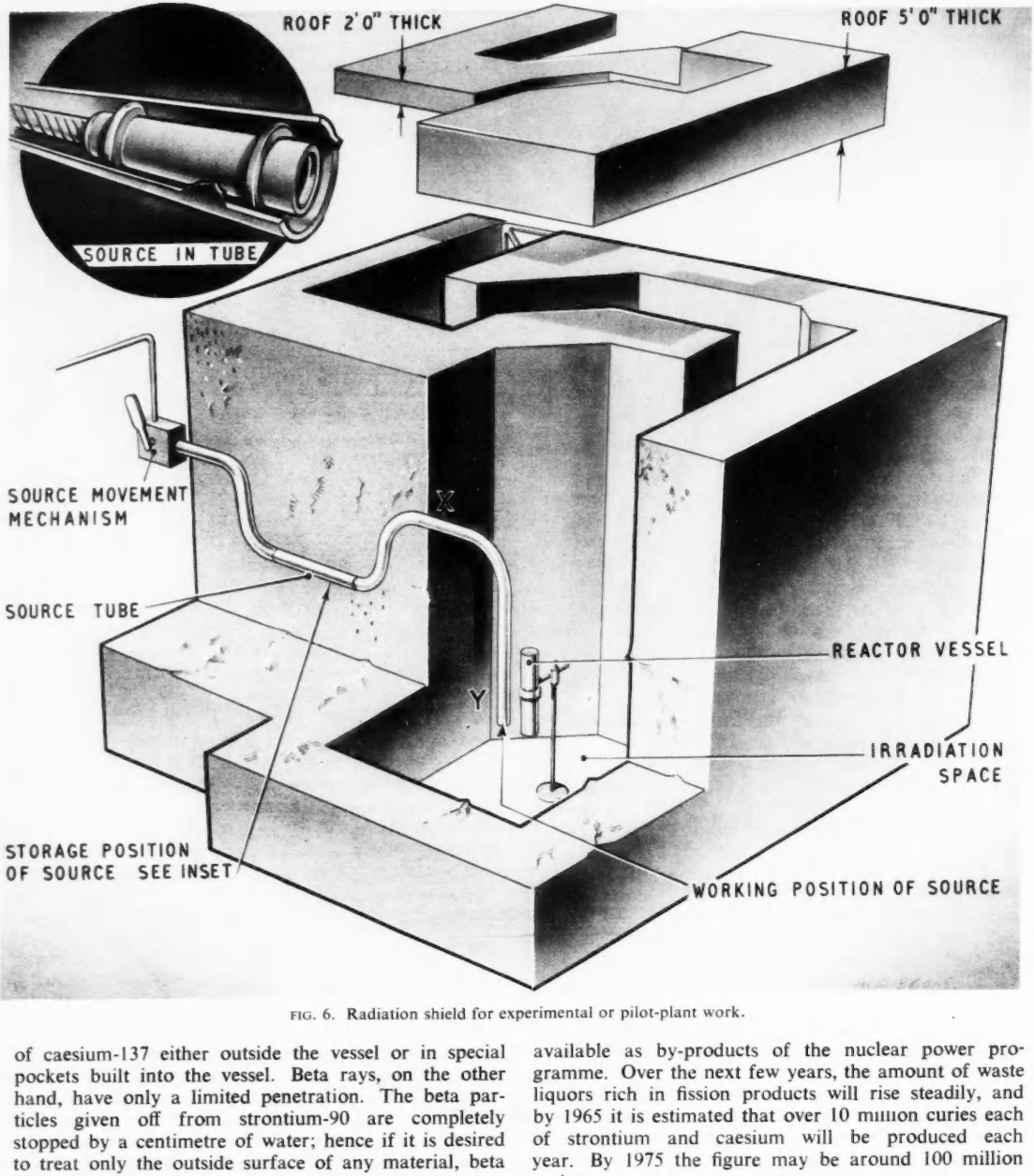

FIG. 6. Radiation shield for experimental or pilot-plant work.

of caesium-137 either outside the vessel or in special pockets built into the vessel. Beta rays, on the other hand, have only a limited penetration. The beta particles given off from strontium-90 are completely stopped by a centimetre of water; hence if it is desired to treat only the outside surface of any material, beta radiation is ideal.

A suggested use for beta radiation is the "surface sterilisation" of meat and eggs. In both these foods the bacterial contamination appears to be mainly on the external surfaces, so that irradiation with beta particles might result in useful sterilisation of the food that did not affect the inside of the food; this would eliminate undesirable off-flavours and odours inevitable with deeper-penetrating radiation.

Very large amounts of strontium and caesium will be available as by-products of the nuclear power programme. Over the next few years, the amount of waste liquors rich in fission products will rise steadily, and by 1965 it is estimated that over 10 million curies each of strontium and caesium will be produced each year. By 1975 the figure may be around 100 million curies.

Before the strontium and caesium can be used industrially it is necessary for them to be separated from the waste liquors. It is unlikely that the liquors themselves could be used for irradiation since the concentration of activity is very low; moreover, the hazards involved in handling radioactive fission products in solution are much greater than would be the case if the active material were solid. Solid fission products could be obtained by simple evaporation of the fission product

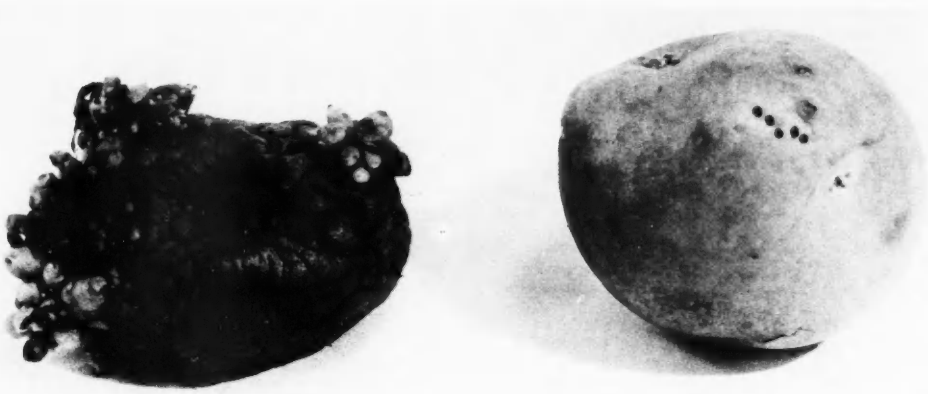

FIG. 7. Suppression of sprouting by radiation has proved effective for both potatoes and onions. This picture comes from the Brookhaven National Laboratory, where food preservation techniques that depend on irradiation are being developed. The two potatoes came from the same 1952 crop, and were photographed on March 18, 1954. The one subjected to atomic radiation (gamma rays) is perfectly preserved: the untreated tuber has sprouted and dried up. Both had been stored under commercial conditions for 15 months.

liquors, but the concentration of strontium and caesium in the resultant solid mass would be quite low. For most purposes, therefore, it will be necessary to separate out the strontium and caesium. A method which might be used to separate caesium and strontium is shown in the flow sheet in Fig. 5.

To make the sources perfectly safe to handle it is necessary to enclose the caesium and strontium salts in suitable containers. In the case of caesium, this is done by adding the concentrated solution of caesium sulphate drop by drop to a cylindrical metal container; continuous evaporation yields a deposit of solid caesium sulphate. The temperature is then raised, and on cooling a dry deposit with the maximum density is obtained. Finally, the aperture in the metal container is closed with a plug and welded. The cylinder (4 inches $\times \frac{1}{2}$ inch internal diameter) may contain about 30 grams of caesium sulphate, with an activity of 500 curies.

Since beta particles are easily absorbed by metals, the envelope enclosing a beta-emitting source must be very thin. A method which has been developed at Amersham is to enclose the strontium in a "sandwich" of silver. This is rolled down until the thickness of silver is only a few thousandths of an inch. Although the largest sources which have been prepared are only 0·5 curie, there is no reason why larger sources should not be prepared. These sources are perfectly safe; it is impossible to remove the strontium from them except by breaking the silver layers.

Considerable thought has been given to the problem of using these radiation sources industrially. There are, in general, two main requirements. Firstly, in order to protect personnel, the source must be adequately shielded; secondly, the mechanisms involved must be safe and easy to operate.

One type of shield which can be used is shown in Fig. 6. This type of irradiation unit is suitable for experimental or pilot-plant work. At the moment this design is being used for sources of approximately 10,000 curies, but with some slight modifications it should prove suitable for sources of up to a million curies. The shield consists essentially of an inner radiation cell with access via a cranked corridor, which prevents scattered radiation from reaching the gate. The source is pushed from its storage position into its working position by means of flexible cable. The source and cable are enclosed in a bent tube (approximately 1 inch outside diameter). When the source is in its storage position, the curvature of the tube prevents the radiation from escaping at either end. Often the tube between *X* and *Y* is made flexible so that the source can be used in any position. Since many such tubes can be put through the shield, it is possible to build up a large source at *Y* from a series of smaller sources. The whole unit is completely interlocked, and gates are provided so that it is impossible to enter the irradiation cell except when the sources are in the storage position. In this safe position they are surrounded by an adequate concrete shield.

On an industrial scale, conveyor belts could be used to carry various materials past the source, and in the case of reactions taking place in liquids, flow systems would be used.

I have given a few examples of the various ways in which radiation might be used industrially. Industrial processing using radiation is only in its infancy, but already discoveries have been made which indicate that the potential industrial uses are considerable. British industry is already showing considerable interest in the uses of atomic radiation, and every effort is being made by the Atomic Energy Authority to encourage research in this field.

READING LIST

Report on the "Utilisation of Fission Products" (a Symposium held at Harwell) by J. Wright and G. Walton. A.E.R.E. C/R 1231. Obtainable from H.M.S.O.

Food Investigation Special Report, No. 61. Scientific and Technological Problems involved in using Ionizing Radiations for the Preservation of Food, by R. Hannen. (H.M.S.O., 1955.)

THE BOOKSHELF

An Introduction to Reactor Physics

By D. J. Littler and J. F. Raffle (*London, Pergamon Press, 1955, 196 pp., 25s.*)

It is a pleasure to welcome at last a book on Nuclear Energy written in Britain. There is a pressing need to introduce the principles of reactor physics to more workers in this country outside the gates of the Atomic Energy Authority. This book should contribute towards this. It has been written, as might be expected, by two Harwell scientists.

The treatment of the subject makes the book self-contained. A brief description of the concepts of atomic physics precedes three chapters outlining the basic ideas of nuclear physics. The conditions required for achieving a chain reaction are calculated, and the diffusion of neutrons through a reactor is investigated in some detail. Reactor kinetics are discussed, and a little is said about the problems of running a graphite-moderated reactor at power. There are chapters devoted to shielding reactors, to the detection of radiation, and to damage to materials. The text is illustrated by line drawings. No material concerning the physics of neutrons (such as neutron diffraction) is included other than that relevant to the maintenance of a chain reaction.

A simple mathematical treatment is given of those aspects of reactor physics which are amenable to such analysis. All the terminology introduced is explained and clearly defined. The whole book can be read with profit by an engineer about to enter the field of reactor engineering. The greater part of it will be of interest to anyone wanting an overall picture of the physical processes involved in the operation of a reactor.

In a book of just under 200 pages it is clearly not possible to give a sufficiently detailed account to enable the most enthusiastic industrial scientist to build a reactor in a spare corner of his laboratory. However, a few additions to this book might greatly enhance its value. The most pressing need is for the inclusion of more references, both for special topics and for discussions of broader issues. For example, there is a chapter of seventeen pages, on devices for counting radiation, but not a single reference to further literature on this important topic. The inclusion of a comprehensive list of neutron absorption cross sections for the more commonly used constructional materials would probably be of interest and value to most readers.

Nowhere in the book is there a description of the various types of reactors that have been operated, such as heavy water moderated reactors, ordinary water moderated reactors, homogeneous fast reactors, etc. It would give the reader a clearer perspective of the problems involved had some of these been briefly described, and their peculiar problems of physics and engineering contrasted. In fact all the calculations relevant to a particular type of reactor, such as lattice spacing, neutron absorption in canning materials, all refer to the graphite moderated lattice. This reflects the interest of the A.E.A. in the speedy development of such reactors for power production. But the horizons of engineers and scientists entering this field should be raised far beyond understanding the present designs. It seems to the reviewer that a treatment of reactor physics divorced from the engineering problems is unrealistic, since there is so strong an interdependence of the two.

In spite of these criticisms the book is to be recommended warmly, and the authors must be commended for having made available so clear an account of the principles of this subject.

B. D. HYAMS

An Illustrated History of Science

By F. Sherwood Taylor. Illustrated by A. R. Thomson (*London, William Heinemann, 1955, 178 pp., 25s.*)

In 1953 Dr. F. Sherwood Taylor, Director of the Science Museum, gave the Christmas Lectures at the Royal Institution, the 126th course of lectures "adapted to a juvenile auditory". Dr. Taylor, whose interests are those of a scientific historian, selected as his topic the history of science and hit upon the admirable scheme of presenting the evolution of his subject by repeating some of the classical experiments of the past in a fashion as near as possible to that of their originators. The Royal Institution is an ideal situation for such a scheme, since a quite surprising number of these advances have been made within its historic walls.

Now Dr. Taylor has published his lectures in book form, but since one cannot carry out experiments in a book, he now presents them as *An Illustrated History of Science*. The illustrations are made up almost equally of reproductions, mostly from contemporary sources, and new sketches by A. R. Thomson, R.A., many of which are of a highly conjectural nature. This being so the question immediately comes to mind, is this an illustrated history of science, or is it a history of science that has been illustrated? The distinction to the reviewers is an important one. An analogy from the world of radio will help to make this point clear.

If one hears a radio talk by an acknowledged expert one starts from the assumption that his facts will be verifiable and his opinions presented as such. On the other hand, if history is presented in the form of what the pundits of Portland Place call a *feature* and it includes a conversation supposed to have taken place between, say, Dalton and Joule, there is a high probability that it is a fabrication and there is a considerable danger that, albeit unwittingly, false impressions are conveyed.

Dr. Taylor of course knows this, and, while he asks the reader to accept Mr. Thomson's sketches as a synthesis of what has been transmitted by documents, one suspects that he really does not expect the scientist and the historian to do so because "in order that the student may not be tantalised" an appendix indicating the source of some of the syntheses is included. It makes interesting reading. It reveals, for example, that frequently, out of forty square inches of picture, all but one is conjectural: the Egyptian sundial, the 15th-century Italian alarm clock, and the sand-glass are prime examples, while the egregious material includes Egyptian beauties who appear to have purchased their night-attire in Shaftesbury Avenue, and John Knox presented as a raving lunatic. (Incidentally, two of the notes in the appendix are misnumbered.)

It must not be thought, however, that the whole of this book is on the same phantasmagorial plane. The verbal pictures are clear and trace the growth of science from Egyptian times to the present age of cyclotrons and nuclear energy. But with such a vast canvas to cover, in a book based on only six lectures, one cannot expect more than a sketch of the development of the subject. This is indeed what one gets, the whole of science since the 18th century being squeezed into one half of the book. In consequence there are many unhappy omissions, and a pronounced bias in treatment towards the physical sciences. Have there been no advances in biology worth noting since the age of Darwin and Wallace, Pasteur and Koch? One looks in vain for a picture of Mendel among the pea-stakes. And since when has Lord Lister become Scottish; a distinguished holder of Scottish professorial chairs, certainly, but English born and educated for all that.

As in so many popular expositions of science, one is uncertain about the target audience, but as this book started from Christmas Lectures at the Royal Institution one might assume that it is aimed at the sixth form. If this assumption is correct, more care might have been given with advantage to presentation: the past participle of show is not showed, alkalis is the accepted plural of alkali, and so on. And shouldn't the Coulomb Law state that

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the attraction between bodies is *inversely* proportional to the square of the distance between them? With so much current criticism of the inability of scientists to present their information clearly and idiomatically, scientific historians must be above suspicion.

A. AND N. L. CLOW

Realms of Water

By P. H. Keunen (*London, Cleaver-Hume Press, 1955, 327 pp., 16 plates, 35s.*)

The author is a distinguished Dutch geologist, and his well-illustrated book is intended for the non-specialist. The first part of it deals extensively with the water of the oceans and seas. It covers the wider aspects of oceanography, tides, salinity and temperature variations as well as the interaction between sea and land.

Then follows a discussion of the role of water in the atmosphere; here two minor criticisms arise. These are upon the diagrams illustrating frontal phenomena. The first, on p. 112, is too diagrammatic and does not give the true curvature of the slower-moving warm front. The second, on p. 123, showing a section through a warm front, would be more accurate if the ascending warm air were slower moving from west to east. The following parts, which deal with water in the solid, in the ground and on the surface are illustrated by numerous diagrams and worldwide references.

This book at the price of thirty-five shillings represents good value for money today. It should appeal to all students of the field sciences whether they are specialists or not.

F. A. HENSON

Electronics

By A. W. Keen (*London, Ward Lock, 1955, 255 pp., 25s.*)

The author's aim is to explain his subject, not by a conventional textbook, nor by a sparse popular work, but in a manner that is both fairly thorough and fairly readable. This middle path is tricky at the best of times, and Mr. Keen should be praised for attempting it with so awkward a subject as electronics.

The need for such a book is clear. Of all the paraphernalia with which science has surrounded us, the electronic circuit is the most pervasive and the most baffling. By a quirk of the educational system, even a physics graduate may be helpless when his wireless set goes wrong. The facts of electronics are normally lodged in handbooks, data sheets and erudite papers—and in the fingers of those engineers who have the knack of making circuits work. To extract a well-ordered and balanced account is quite a problem, even for a teacher like Mr. Keen. He probably found the task valuable for himself, because merely to be rid of the mathematics has entailed a careful regard for first principles.

Throughout the book he wisely emphasises the ultimate uses of the valves. He surveys the whole field in very general terms, before explaining the role of the electron in atomic physics and the conduction of electricity. He deals broadly with the properties of the chief types of valves, and then discusses the nature of electronic signals and the basic circuits for handling them. The latter half of the book is a full account of electronics at work, in power control, radio, radar, television, computing and instrumentation. By continually moving from applications to valves and back to more applications, Mr. Keen is able to pack the pages with information without ever seeming to be academic. His style is clear and to the point, and four dozen excellent photographs enliven the text.

A number of minor faults combine to narrow the usefulness of the book. The treatment is uneven; Mr. Keen takes pains to expound Ohm's law and electrolysis, but skims through electron configurations and semi-conductors. No recapitulation is allowed, and once a term has been defined it is used freely, though checking-back is difficult with the scanty index provided. Some words, like diffraction and impedance, have slipped in unexplained. One or two small errors will puzzle the beginner—what, for instance, is a gas-filled high-vacuum diode (p. 37)?

I think that only the most attentive layman can be advised to read this book. On the other hand, a student working for examinations may not find the treatment thorough enough. It will suit best the scientist or trained amateur who is needing electronics for the first time, and who will appreciate a concise, simple and readable introduction to a vast subject.

NIGEL CALDER

Nuclear Radiation Detectors

By J. Sharpe (*New York, John Wiley; London, Methuen, 1955, 179 pp., 11s. 6d.*)

This addition to the well-known series of Methuen Monographs on Physics discusses the details of the performance of signal-producing detectors for the measurement of α, β, γ rays and beams of protons, neutrons, fission fragments, etc. The detectors discussed are the familiar ionisation chambers, proportional counters and Geiger counters, together with the more recent conduction and scintillation counters. The Wilson Cloud chamber and nuclear emulsion techniques are omitted on the ground that they are "passive" detectors which produce visible tracks rather than electrical signals.

The design and use of particular detectors is preceded by chapters summarising, first, the possible interactions of neutrons, photons and charged particles with matter and, secondly, the properties of the phosphors and ionisation media used in the detectors. This section of the book contains a wealth of experimental data derived from nearly 200 original papers and project reports.

The inclusion of so many tables and graphs giving this valuable information makes the book a reference work rather than a readable introduction to the subject, which is better obtained from Taylor's *Measurement of Radio Isotopes*, published in the same series. Altogether over 400 references (up to 1954) are included; one of them (p. 36, ref. 40) is dated optimistically 1962! Unfortunately, there is at present no detailed index, but later editions will no doubt have one.

E. R. DOBBS

Practical Organic Gardening

By Ben Easy (*London, Faber, 1955, 312 pp., 21s.*)

The emphasis in this book is on the *practical* use of organic matter for the amateur gardener, the market grower and the farmer. The author, in the opening chapter, gives an account of the need to maintain fertility in nature, the importance of soil organisms and the purpose of organic cultivation. While he realises that lime is necessary (and the soil of Britain is still generally deficient in lime) he states that crops can be grown successfully without the use of artificial fertilisers. But the market grower and the farmer grow crops for profit. And it has been shown conclusively in the last few decades that artificial fertilisers used with organic manures produce the best yields, especially for arable farmers growing the new varieties of wheat, barley and oats. It is significant that the British farmer still uses little more than half as much nitrogen and potash as his neighbours in western Europe. As Sir James Scott Watson said recently, "There is some prejudice against heavy use of so-called artificials . . . but the greater use of fertilisers, if rightly used, produces a bigger stock of organic material—richer swards to plough down, and more straw and fodder to turn into muck." But it is in the practical chapters on the making of compost, selection of materials, application and cultivation, that this book makes a real contribution to horticulture. Many growers, both amateur and professional, must rely on compost to provide their organic material—especially those who live in our cities and have no access to farmyard manure. This book will give many useful hints on how to get along with compost from the waste material of the garden. The book is splendidly illustrated, and indeed is a first-class production. The author has provided an excellent index, and three most interesting appendices for those enthusiasts of composting who may wish to continue their study of this fascinating subject.

H. HOGGAN

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The British Journal for the Philosophy of Science

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NEW SCIENTIFIC INSTRUMENTS

This feature is designed to provide information about new scientific instruments which have come on the market. The detailed facts in it are the responsibility of the manufacturers, being taken from literature supplied by the makers. The editor will welcome information from manufacturers about new scientific instruments they are putting on the market. As these notes are intended for the large section of our readership composed of professional scientists, etc., we depart from our customary practice and use symbols and abbreviations to the full in order to be able to convey the maximum amount of detailed information.

Automatic Point Counter

The Swift automatic point counter is an instrument for the analysis of any material or mixture (e.g. mineral aggregates, cements, rubbers, refractories, biological and organic materials) whose constituents are identifiable under a microscope. The eyepiece of the microscope must be fitted with a fine cross-lined graticule; the centre of this is used as a point of location.

The instrument consists of a traversing-carriage, which may be attached to the stage of any conventional microscope fitted with either transmitting or incident illumination. It is coupled to an electrical recording or counting unit controlled by the observer. The traverse of the specimen carriage is broken into a series of equally spaced steps, triggered electrically in the "horizontal" direction by switches in the counting unit, and manually in the "vertical" direction by a control knob, making a symmetrical grid of points. The series of push-buttons in the counting unit is labelled appropriately to correspond with the identifiable constituents of the material under examination. To operate the device, the observer identifies a particle under the cross-wires and depresses the appropriate counting button. This automatically moves the specimen on one space and the observer repeats the process over one complete horizontal traverse. After restoring the carriage to its original position he selects the next horizontal traverse by moving the vertical spacing knob. The instrument is supplied with four horizontal intervals of traverse (1/20, 1/10, 1/6 and 1/3 mm.). The vertical spacing is 0·3 mm.

Six counters provide for the tabulation of six possible constituents in the specimen. The seventh gives the total of all recordings or may be used for an emergency seventh constituent.

James Swift & Son Ltd., 113–115A Camberwell Road, London, S.E.5.

Square-Wave Polarograph

In the Mervyn-Harwell square wave polarograph, designed by Barker and Jenkins at the Atomic Energy Research Establishment, Harwell, derivative polarography enables the slope of the current/voltage curves to be obtained automatically, and the normal polarographic steps are recorded as peaks on a Honeywell-Brown recorder. A square-wave voltage is applied to the polarograph cell, superimposed on the normal slowly changing d.c. voltage; and peaks corresponding to the reduction of certain metallic ions can be isolated at very low concentrations.

Its sensitivity is claimed to be one hundred times greater than that of the normal classical equipment: minor constituents of 0·001% can be detected in samples of 20 mg.

Mervyn Instruments, St. John's, Woking, Surrey.

Particle Size Determination Apparatus

This instrument was devised by W. Bostock and described in the *Journal of Scientific Instruments* (1952, vol. 29, p. 209). It consists of a sedimentation system, a receiving tank and a direct reading torsion balance, all mounted on a levelling stand. It enables the size of particles to be determined in the sub-sieve range 5–75μ; or if the top size is not greater than, say, 20μ the lower limit can be extended to about 2μ. A powder uniformly dispersed in a suitable liquid is introduced into the sample container and the particles allowed to settle on the pan of a special torsion balance. The pan is suspended in clear liquid and the weight indicated by the balance is unaffected by changes in the density of the suspension. The balance is sufficiently sensitive for very low concentrations of solids to be used, allowing sedimentation under practically free falling conditions and negligible interference with free falling particles. Readings are taken at suitable time intervals until sedimentation is complete. The weight-size distribution is readily calculated from the density of the powder and the density and viscosity of the liquid.

A. Gallenkamp & Co. Ltd., 17–19 Sun Street, London, E.C.2.

High-Speed Camera

The optical system used in the C.P. High-Speed Camera (the main lens being an 8-in. *f*2·9 Dallmeyer Penetac) enables a series of 200 photographs to be taken at speeds ranging from 100 to 100,000 pictures per second. This is made possible by the use of a large assembly of tiny lenses, embossed in plastic and bonded on to a glass plate, which dissect each picture into small elements, each separated from its neighbours by a distance large compared with the size of the element. By rotating a Nipkov disc, in the aperture plane of the main camera lens, each picture element is displaced and thus successive pictures are recorded on one place. (A Nipkov disc has a series of holes arranged in an arithmetic spiral.) The recording rate is controlled by the rate of revolution of the disc. The 5×4-in. plate, after processing, is replaced in the carrier, and a bright light source introduced into the main camera lens. Silhouette pictures are then seen on a ground glass plate at the rear of the carrier. The rotation of the disc shows the series of photographs, originally recorded at high speed. The disc may be stopped at any time during its rotation and a simple contact print taken of the event photographed at any or all stages of its progress.

The device, due to Dr. J. S. Courtney-Pratt, was described in detail by him in the *Journal of Photographic Science*, 1953, vol. 1, p. 21. It is specially useful for the study of rapidly recurring events, such as combustion, electrical discharges, ballistics, vibration phenomena, detonation, etc. The camera is manufactured under licence from the National Research Development Corporation.

J. Langham Thompson Ltd., Bushey Heath, Herts.

New Weston Standard Cell

The new miniature standard cell (Type D698) combines robustness and small size with a high capacity previously only available in larger types. The manufacturers have reverted to the classical H construction, modified to minimise the temperature difference between the legs of the H and the resultant changes in e.m.f. Connexions are brought out to two terminals at the top of the case and provision is made for base or side mounting. The cell is intended for vertical use but a misalignment of several degrees will not affect its performance.

The e.m.f. is 1·01859V absolute, guaranteed to within +110μV and −90μV at 20°C for individual cells. The e.m.f. varies with temperature from 1·01889V absolute at 10°C to 1·01748V absolute at 40°C. The internal resistance is 600Ω at 20°C. Short period discharge current is 20μA.

Muirhead & Co. Ltd., Beckenham, Kent.

FAR AND NEAR

The Royal Society and the State

At the anniversary meeting of the Royal Society on November 30 LORD ADRIAN, the retiring president, inducted his successor, PROF. SIR CYRIL HINSHELWOOD, who is Lee's Professor of Organic Chemistry at Oxford.

In his address LORD ADRIAN spoke of the relationship of the Royal Society to the State. "We have never aspired to an organised control of scientific research," he said. "Even in times of grave national emergency we have preserved our status as a private body willing to co-operate with the State but unwilling to forfeit our independence." The Society administers yearly Government grants of over £50,000, but the value of the Society's own funds amounts to over £1 million. "These sums, however, are small compared with the total which must be spent annually by any country dependent on machinery, and with the political system of this country it seems far better for the Royal Society to keep itself outside the State organisation," he added.

Sometimes the Society has been asked to produce reports on special matters, and Lord Adrian instanced the report of the Food Committee it set up in World War I. "That is the kind of obligation which the Royal Society should be specially fitted to discharge. It is right that the State should obtain the best scientific advice on practical issues and it must know where to turn for the best panel of advisers. But it has never been suggested that the Society assumed any other responsibility than that of choosing the committee of experts to draw up the report."

Today there are specialist societies as competent to nominate experts in particular fields, but the fragmentation of science leaves disputed borderlines as well as unclaimed territory. "If our Fellows have been properly chosen we should be able to justify the claim to represent all branches of science at the highest available level. Although we do not pronounce officially on matters of scientific controversy, we can say who are the leaders in any field and we know what sort of people they are."

Lord Adrian referred to the scientific activities of Government departments. The State is forced to spend more and more of its income on science and technology, and expand research, teaching and development. But, said Lord Adrian, it must be careful not to harness too many active investigators to desks in Whitehall or to committee rooms.

The meeting elected PROF G. L. BROWN biological secretary who succeeds SIR EDWARD SALISBURY, who retires from the post after ten years' service. DR. H. G. THORNTON, head of the Department of Soil Microbiology at Rothamsted, was elected foreign secretary.

The following medals were presented: COPLEY MEDAL to Sir Ronald Fisher, ROYAL MEDALS to Sir Alexander Todd, and to Prof. V. B. Wigglesworth, the SYLVESTER MEDAL to Prof. E. C. Titchmarsh, and the HUGHES MEDAL to Prof. H. S. W. Massey. Prof. H. W. Melville, who could not attend, receives the DAVY MEDAL.

Russian Scientists Visit Britain

Academician A. N. Nesmeyanov, President of the U.S.S.R. Academy of Sciences, led the delegation of prominent Russian scientists, who arrived in London on November 15. The visit was arranged by the Royal Society in association with the Soviet Relations Committee of the British Council. Other members of the delegation included a woman hydraulics engineer, P. YA KOTCHINA; Academician I. G. PETROVSKY, mathematician and Rector of the University of Moscow; Academician A. L. KURSANOV, plant physiologist; Academician V. A. KARGIN, physical chemist.

Their visits took them to the Universities of Cambridge, Edinburgh and Oxford, and to the National Physical Laboratory and Rothamsted. They were guests of the Royal Society at its anniversary dinner, and Academician Nesmeyanov read a paper at one of the Society's Thursday meetings. The Parliamentary and Scientific Committee gave the party a reception in the House of Commons.

Atomic News

The British Nuclear Energy Conference had an extremely successful first meeting on November 30, when the speakers included SIR CHRISTOPHER HINTON and SIR JOHN COCKCROFT. About 1300 people attended.

A joint paper by MR. V. A. PASK and MR. J. C. DUCKWORTH (Central Electricity Authority) gave figures showing that the Government White Paper on atomic power was now very much out of date. The estimated electrical power deficiency in 1965 would be about 4000 megawatts, instead of 1500–2000 megawatts. To fill this larger gap there would need to be an expansion of the nuclear power programme or additional coal or oil generators.

Health hazards and health precautions in atomic plants were discussed by DR. A. S. MCLEAN and DR. W. N. MARLEY. Figures compare favourably with those in older industries, but DR. MARLEY pointed out that expenditure by the Atomic Energy Authority on services concerned with safety precautions directly concerned with personnel amounted to £50 per head annually.

The B.N.E.C. is a joint enterprise sponsored by five organisations, and it is designed to enable members of the four engineering institutions (the Civil, Electrical, Mechanical and Chemical) and the Institute of Physics to keep informed on the development of nuclear engineering. Its secretary is MR. ALEXANDER MCDONALD (secretary of the Institution of Civil Engineers, Great George Street, London, S.W.1).

Another B.N.E.C. meeting was held on December 14. This was organised by the Institution of Mechanical Engineers. A single paper was presented —"The Pressurised Water Reactor as a Source of Heat for Steam Power Plants," by J. M. KAY and F. J. HUTCHINSON.

* * *

The Scientific Instrument Manufacturers' Association has formed a permanent Nucleonics Group. Mr. R. Y. PARRY (Ekco Electronics Ltd.) is its chairman, and Mr. H. A. LUSS (Isotope Developments Ltd.) vice-chairman.

Well over half of the 140 member firms of the Association are engaged in some aspect of the field of atomic energy applications, by the provision of electronic, mechanical and optical instruments and equipment, both laboratory and industrial.

SIMA has been active in the field of atomic energy, nucleonics and radioisotopes for a considerable time, and at the suggestion of the Atomic Energy Research Establishment, Harwell, has acted as a liaison body for over a hundred equipment manufacturers.

To demonstrate the importance of applications of atomic energy to a wider field at home, SIMA is organising an exhibition with the theme "Atoms, Electrons and Industry" in Bristol from June 6 to 8. Inquiries should be sent direct to SIMA, 20 Queen Anne Street, London, S.W.1.

* * *

Fourteen British firms exhibited their latest nucleonic instruments at the Atomic Exposition held in Cleveland in December.

The "Atoms for Britain" exhibition, which the A.E.A. staged at Geneva, will be seen for the first time in this country at this year's British Industries Fair at Earl's Court (February 22–March 2).

* * *

According to *The Financial Times* (25.11.25), at least four British firms are studying the possibilities of atomic aircraft engines. This newspaper specifically mentioned the following companies: Hawker Siddeley, Bristol Aeroplane Co., Rolls-Royce and A. V. Roe. As was mentioned in our report on the international atomic conference (DISCOVERY, October 1955, pp. 412–20), the first three companies sent official observers to Geneva.

* * *

The Atomic Energy Authority deposits copies of all its unclassified

The new Underwater Hydrodynamic Laboratory at the Admiralty Research Laboratory, at Teddington, houses some unique equipment. The most spectacular item is a 60-ton rotating beam, which has an overall span of 122 feet. The beam rotates above a circular trough of water; this is rectangular in cross section, is 34 feet wide and 15 feet deep, and holds a million gallons of water. The model (which can be up to 20 feet long) is carried on a strut attached to the beam, and travels round the trough at speeds of up to 100 knots; it is submerged the whole time, to a depth of 5 feet. The water is chlorinated to prevent the growth of algae, and it is specially filtered to make it clear. The behaviour of the model can be observed and photographed through observation windows in the side of the trough. The picture shows the rotating beam, and the control panel being operated by Mr. O. L. Burkett.

documents with five additional libraries: these include four central libraries (Birmingham, Liverpool, Manchester, Newcastle), and the Mitchell Library, Glasgow. Other libraries which have complete sets of these documents are the Science Museum Library and the Patent Office Library in London, and the Sheffield Central Library. From all of them photostat copies can be supplied at the usual rates. A monthly list of A.E.A. documents available to the public in depository libraries is issued from the Atomic Energy Research Establishment at Harwell. Requests to be put on the mailing list should be sent to the Librarian, A.E.R.E., Harwell, Didcot, Berks.

* * *

The Institute of Metals has appointed a nuclear energy committee to stimulate interest in metallurgical problems in the industrial and scientific use of nuclear energy.

The Engineering Industry's Demand for Graduates

The Advisory Council on Scientific Policy, which advises the Lord President of the Council on matters of Government scientific policy, has been studying problems that affect the recruitment of graduates and apprentices by the engineering industry. The Advisory Council (through its Committee on Scientific Manpower) collected facts and opinions from leading engineering firms and also from four nationalised industries—National Coal Board, British Railways, Central Electricity Authority and the Gas Council—and some of these are now published in the document entitled *Report on the Recruitment of Scientists and Engineers by the Engineering Industry* (Stationery Office, 1*s.* 3*d.*). It is estimated that the firms consulted recruited over half of the number of young engineering graduates finding jobs in industry in the last few years. (The report gives the annual average intake for these firms as 974 graduates.) The inquiry was prompted by reports that some firms viewed with misgiving the expansion of higher technological education and research at the universities.

The results of the inquiry show that there is a substantial unsatisfied demand for engineering graduates, especially for graduates with good honours degrees and capacity for leadership. The report says that the universities are producing only three-quarters of the graduates that British firms want. One firm is quoted as saying "*we have the greatest difficulty in recruiting graduates even with third-class honours*".

Some firms are worried about the effect of an expansion of the universities on the numbers and quality of boys available for training as apprentices. The Committee on Scientific Manpower does not consider that this represents a real danger. It points out that there is an ample reservoir of untapped talent in the country and that the real objective should be to persuade more boys of outstanding ability to choose engineering as a career. Careers in industry, particularly the engineering industry, appear less attractive to boys of intellectual ability and outstanding character, says the committee, which adds that the responsibility for conveying the fact "that engineering can be as rewarding, intellectually and materially as any other career" rests particularly with schoolteachers and parents. (It would seem to us that a larger public relations campaign by the industry is also required.)

The inquiry shows that some firms are doubtful about the value to industry of post-graduate research in engineering at the universities. Firms interested in recruiting graduates prefer to take them at first degree stage: "It is argued that a graduate who spends an extra two years at the university on work which is generally held to be of doubtful value, and then two years on National Service, will not be ready to enter industry until he is at least twenty-five years old. This delays too much the age at which he should be ready to assume effective command." But the report does not consider that any change in university plans to expand post-graduate work in engineering would be justified, as the scale of post-graduate research work planned is in general no greater than is necessary to ensure that university engineering departments will thrive as scientific institutions. It adds there is an urgent need for more post-graduate instructional courses, as opposed to research.

The document contains a brief description of the apprenticeship schemes at present in existence in the engineering industry, and summarises the varying views expressed by firms about the value of training the "hard way" as compared with that given by universities. Many firms are coming to regard some kind of "sandwich" scheme as the best solution. The normal type of such schemes is for boys to spend six months of the year in a technical college and the rest of the time at the works. But many firms now favour a "1:3:1" system in which boys spend one year in industry, three years at a university and then a final year in industry.

974 is given as the figure for the average annual intake of science and technology graduates for the fifty firms consulted. The comparable figures for holders of national certificates, student apprentices and trade apprentices are 293, 1173 and 4156 respectively.

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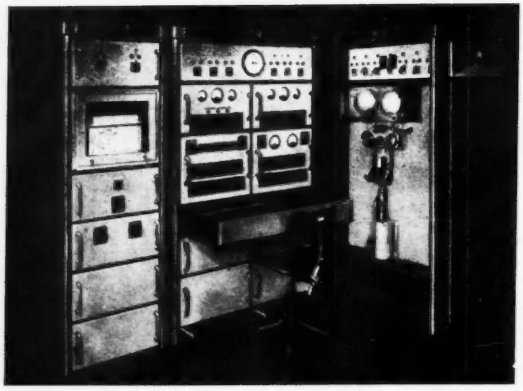

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Enriched Mass 115	0·70	0·37	**11·2**	35·8	10·3	19·0	15·0	6·2	0·81	0·65
117	0·56	0·16	0·47	3·2	**69·9**	14·0	2·7	2·9	5·7	0·44
118	0·22	<0·04	<0·04	0·25	0·93	**94·1**	2·95	1·36	0·08	0·10
119	0·33	0·11	<0·04	0·49	0·72	18·5	**71·7**	7·3	0·67	0·22
122	0·20	0·34	0·34	2·1	8·7	5·1	2·6	3·4	**75·3**	1·95

The table illustrates the application of the MS2 to Isotope assay work. Samples of stannic chloride enriched by electro-magnetic separation, were analysed and compared with a normal sample. The figures in bold type are the final amounts of the particular isotopes in which the samples were enriched.

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Some of the vacancies are in new laboratories in Coventry and although all are in the Research Department in the first instance, opportunities will arise for transfer to Production Departments and other activities within the Company.

Candidates should write for a detailed form of application to the Director of Personnel, Courtaulds Limited, 16 St. Martins-le-Grand, London, E.C.1, quoting the appropriate reference number.

FAR AND NEAR—contd.

The Night Sky in January

The constellation Cassiopeia is conspicious, and is easily found by drawing a line from the last star in the Great Bear's tail through the pole star and producing it as far as these two stars are apart. The line will pass through Cassiopeia, also known as The Lady in the Chair, easily recognised from its resemblance to the letter *W*. If moonlight is not too strong it can be observed that it is immersed in the Milky Way. The chief stars in this constellation, starting with the most western one, are Beta, Alpha, Gamma, Delta and Epsilon. This constellation contains several star clusters and one of these can be seen with the aid of binoculars or a small telescope. It lies close to Delta and on the line between Delta and Epsilon. Another one—not so easily seen because the stars in it are faint—lies practically midway between Delta and Epsilon, but slightly west of the line joining these stars. Sweeping over the constellation with binoculars, you can see many faint stars that are invisible to the naked eye, especially on its western side.

Turning to the planets, *Venus* sets at 18h 25m, 19h 10m and 20h, on January 1, 15 and 31, respectively, and can be seen in the western sky, but not at a great altitude. *Mars* rises in the morning hours—about 4h 10m—but lies rather low for good observation. *Jupiter* rises at 20h 40m, 19h 35m and 18h 20m, on the same dates and is visible throughout the night a little east of the bright star *Regulus* at the beginning of the month, but very close to it towards the end of the month. *Saturn* rises in the early morning, at 4h 50m, 4h and 3h, on the corresponding dates, and towards the end of January is just north of the constellation Scorpius.

Can Britain Train More Physicists?

A report published by the Institute of Physics finds that present university departments could absorb 170 more honours students in physics—representing an extra 25% over present figures. As a corollary, it says there is little need for full-time courses leading to honours degrees at technical colleges. The report is unhappy about the proportion of failures on these courses: it quotes a 1949 figure of 122 failures out of a total of 367 students. The suggestion is made that there is a lack of appreciation in schools of the requirements for admission to physics honours courses and, in particular, a lack of appreciation of the high degree of mathematical ability essential. An article in the journal of the Assistant Masters' Association takes up this point, and makes this comment: "This is a thoroughly depressing document for the average, hard-working, conscientious, sixth-form physics master of a grammar school to read. For there would appear to be so much wrong on his side of the fence and nothing wrong on the university side. Those teaching in universities must surely realise, one might almost say remember, the conditions in the schools which provide the university intake. Not many Sixth Form physics groups including, as they must do, potential doctors, teachers, botanists, biochemists, research chemists, etc.) can have their work and pace based upon the needs of one possible candidate for an honours physics school. . . . There are those who have been rather struck by the brilliance of mind of some boys with whom they have been in daily contact for seven or eight years, only to be staggered by the depth of tarnish developed in three or four years of unburnished existence at the university. It seems to be a poor attempt to measure up our resources in this emergency by the final conclusion 'that in any discussion of the possible expansion of the facilities for higher technological education it is essential to realise that the main obstacle is the shortage of students of adequate quality'."

Radio-astronomy at Cambridge

Cambridge University has accepted the offer of the Mullard Company to provide over a period of ten years the sum of £100,000 for the purpose of continuing and extending the work in radio-astronomy which is in progress under Mr. M. Ryle, F.R.S., of the Cavendish Laboratory. With this money it is intended to set up a new observatory to be known as the Mullard Radio-Astronomy Observatory. Important work in radio-astronomy was started soon after the war in Cambridge under Mr. Ryle. Special types of radio-telescope have been developed and used for detecting the radio stars and for special investigations of the sun. Nearly 2000 radio stars have been charted. A new radio-telescope with greater range is now under consideration.

Deferment for Science Teachers

The Ministry of Education has now circulated details for the deferment scheme, which applies to men with first or second class degrees in science or mathematics and starts to operate on January 1. The Ministry memorandum (No. 576) states that applications for deferment must be made by the employer or prospective employer to the Ministry of Education, whose sponsorship is needed before the Ministry of Labour can grant deferment.

Study of Social Insects

A British Section of the International Union for the Study of Social Insects has now been formed. The subscription is ten shillings a year. Inquiries should be sent to the section's secretary, Dr. C. G. Butler, Rothamsted Lodge, Hatching Green, Harpenden, Herts.

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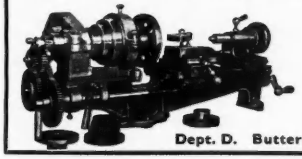

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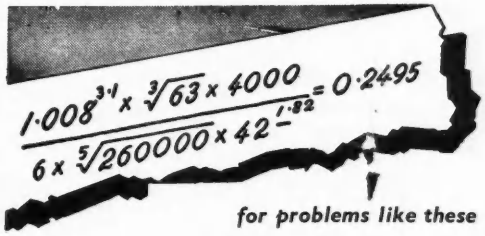

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